MICROCLIMATOLOGICAL, PEDOLOGICAL, AND GEOMORPHOLOGICAL STUDIES IN THE WESTERN TASERSIAQ AREA, GREENLAND, DURING SUMMER 1964

FINAL REPORT

K. R. Everett, N. Holowaychuk
F. Loewe, A. Kryger

November 1965

U. S. Army Natick Laboratories
Natick, Massachusetts

Contract No. DA-19-129-AMC-301(N)

The Ohio State University
Research Foundation
Columbus, Ohio

Final Report
RF Project 1830

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FOREWORD

During the summer 1964, personnel of the Ohio State University Institute of Polar Studies conducted a field program in the Sukkertoppen Ice Cap area of southwest Greenland. The program included studies of soil and mass wasting in the Tasersiaq area immediately east of the ice cap, and studies of the microclimatology across the eastern edge of the ice cap.

The results of this research program are contained in four parts. Part I, by Adolph Kryger, discusses the microclimatological (excluding radiation) results of observations taken at four stations, one at the base of the slope below the eastern edge of the Sukkertoppen Ice Cap, two intermediate ones on the slope, and one at the edge of the glacier. Part II, by Fritz Loewe, discusses the radiation observations. Both have related their observations to those at other permanent stations along the western Greenland coast.

Part III, by K. R. Everett, presents the results of studies of mass-wasting and patterned ground phenomena. The final report, which has been accepted for publication by the Meddelelser om Grønland and is now in press, is very long; therefore, only the abstract is included here. Reprints of the complete article will be forwarded to the Natick Laboratories as soon as they are available.

Part IV, by N. Holowaychuck and K. R. Everett, contains most of the results of the pedological studies. The report herein includes the discussion of soil morphology, chemistry, and classification. The detailed soil map is not included here because it is still being prepared by Dr. Everett at the Natick Laboratories and will require several more months before it is completed. At that time, Part IV will be revised and, with the map, will be submitted for publication in Arctic.

The summer 1964 program was supported by U.S. Army Natick Laboratories Contract No. DA-19-129-AMC-301(N). Additional support was given by The Ohio State University Mershon Fund. MATS provided transportation of personnel and equipment between McGuire Air Force Base, New Jersey, and Søndrestrøm Air Base, Greenland. Military personnel at Søndrestrøm were very helpful. The interest of the MARS operators enabled radio contact to be maintained between the air base and the base camp.

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I. MICROCLIMATIC OBSERVATIONS

by

A. H. Kryger
Institute of Polar Studies
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ABSTRACT

During the study of the summer climate of the Tasersiaq Region of West Greenland, the following phenomena were observed:

1). On clear days the katabatic winds have a greater influence on the minimum temperatures than they do on overcast days.

2). The temperature ranges were greater at a glacier station than on an isolated mountain top under clear sky conditions; the differences are obliterated during 10/10 sky cover.

3). The area as a whole received scanty precipitation; for example 65 mm. fell at Base Camp in 12 weeks. With southeasterly winds, precipitation can be expected. Heavy precipitation was of a local nature while precipitation in small amounts was experienced over a greater area.

4). The humidity profile in the area was influenced by the wind direction. A normal pattern existed except when the winds in the valley were northerly. Then the profile was reversed at the ice edge and glacier stations.

5). On August 4, 1964 a small "twister" was observed in the Lake Quantum area.

INTRODUCTION

During the summer of 1964 a team from the Institute of Polar Studies, The Ohio State University, made meteorological observations in the region south of Søndre Strømfjord in western Greenland (Fig. 1). The observations were a continuation of preliminary weather observations made during the summers of 1962 and 1963 (Loewe, _et al_., 1962; Kosiba and Loewe, 1964). The objective was to study the microclimate of the area and to provide background information for other studies such as glaciology and biology.

The study area is at the west end of Lake Tasersiaq (Fig. 1). The lake lies in a wide valley with mountains to the north and south. The lake level, about 706 m above sea level, varied by 0.5 m during the summer. The northern mountains rise from the lake shore to about 1000 meters above sea level;

the southwestern side reaches a height of 1200 meters above which is the Sukkertoppen Ice Cap, reaching an elevation of 2000 meters. Tasersiaq extends 80 km to the east, to the edge of the main continental ice sheet. The outlet for the lake to the west is through the narrow winding Sarfartoq gorge to Søndre Strømfjord.

The recording instruments were installed and serviced and the visual observations were taken by Mr. James Havens, Lt. David Saarela, USMC, and the author. The observations cover the latter part of June and the months of July and August at "Base" camp and the latter part of July and the month of August at the other stations (Table 1). The time used for the observations was G.M.T. minus 3 hours, so that local noon occurred at about 11:32 clock time. The radiation measurements, however, were made at true local time.

Some meteorological data from Dye I and Søndrestrøm Air Base have also been used. The latter is situated on loam terraces at the head of Søndre Strømfjord, 50 meters above the level of the fjord. The former is located on a mountain top, Qaqatoqaq, north of the mouth of Søndre Strømfjord (66°38'N, 52°52'W, 1450 m)(Kosiba and Loewe, 1964).

Five observation stations were established in the Lake Tasersiaq area and an additional anemometer was located at the shore of the lake (Map, Fig. 1). Table 1 gives the instrumentation and type of terrain at each station, and the period it was in operation.

TEMPERATURE

Table 2 contains the mean maximum and mean minimum temperatures in degrees fahrenheit for each week and each month. These data at Base Camp were obtained from thermometer readings taken at 0700, 0900, 1200, 1500, and 2100 hours, supplemented by thermograph recordings. The thermograph was checked each time an observation was made. For the other stations in the Tasersiaq area the data are from thermographs installed in standard weather shelters. The thermographs were checked weekly against calibrated mercury thermometers. The temperatures at Søndrestrøm Air Base are from hourly observations at the air base weather stations, and those for Dye I are from observations at 0000, 0600, 1200, and 1800 hours.

The extreme temperatures are given in Table 3. The extreme maximum temperature was on August 15 during the passing of a high pressure center. The highest pressure during the season at Base Camp, also on 15 August, was 946 mb (27.92 inches). Compared to the 1963 season the extreme temperatures are shown in Table 4.

TABLE 1. Stations and instrumentation established in Tasersiaq area, summer 1965

Station	Elevation	Type of Terrain	Instrumentations	Operation
Base Camp	723 m	Kame Terrace, sand and gravel	Micro-barograph Hygro-thermograph Assmann psychrometer Max. and min. thermometer Selfrecording anemometer Rain gauge Totalizing raingauge	8 June - 31 August 1964
Intermediate Station #1	873 m	Valley, sand and gravel	Hygro-thermograph Max. and min. thermometer Rain gauge Totalizing anemometer	17 July - 31 August 1964
Intermediate Station #2	995 m	Valley, sand and gravel	Max. and min. thermometer Rain gauge Totalizing anemometer	19 July - 31 August 1964
Ice Edge	1100 m	Crest of moraine sand and gravel	Hygro-thermograph Max. and min. thermometer Selfrecording anemometer Totalizing rain gauge (established 24 July '64)	13 July - 31 August 1964
Glacier Station	1224 m	Outlet glacier snow surface	Hygro-thermograph Max. and min. thermometer Totalizing anemometer Rain gauge	14 July - 30 August 1964

TABLE 2. Mean maximum and minimum temperatures (°F) by week and month

Week / Station	June 15-21	June 22-28	June 29 to July 5	July 6-12	July 13-19	July 20-26	July 27 to Aug. 2	Aug. 3-9	Aug. 10-16	Aug. 17-23	Aug. 24-30	June		July		Aug.	
Søndrestrøm A.B.	56.3 41.2	45.3 34.3	60.3 40.6	54.0 41.9	54.3 39.7	50.9 39.2	92.7 36.0	59.9 42.8	62.8 40.3	53.2 37.8	52.3 33.4	9-30 9-30	52.2 38.3	1-31 1-31	54.3 39.9	1-31 1-31	57.6 38.3
Base Camp	45.3 *2	39.4 27.1	51.3 35.4	47.7 35.1	44.8 33.1	44.8 32.7	45.1 34.7	51.6 38.3	50.5 37.7	46.8 34.3	48.4 29.66	9-30 22-30	43.9 39.2	1-31 1-31	46.4 34.0	1-31 1-31	46.4 35.2
Intermediate Station #1						40.3 31.3	42.8 32.4	47.1 37.0	57.0 43.2	42.1 33.1	44.1 30.0			17-31 17-31	40.5 32.0	1-31 1-31	47.1 35.6
Intermediate Station #2						39.7 29.3	41.4 29.5	46.9 35.6	57.4 41.0	43.7 30.7	42.8 27.0			20-31 20-31	43.3 31.6	1-31 1-31	46.9 33.6
Edge of Icecap					*1 *1	38.3 31.3	39.7 30.0	43.9 35.8	53.6 39.0	40.6 31.4	40.6 27.7			20-31 20-31	42.1 33.8	1-31 1-31	44.6 33.1
Glacier Station						33.4 27.9	35.4 26.6	40.6 34.0	45.9 37.4	39.7 29.7	36.3 25.3			15-31 15-31	32.9 27.0	1-30 1-30	39.0 30.2

*1 snow blew into instrument causing part of record to be destroyed.

*2 indicator shook into bulb or moved.

TABLE 3. Extremes of temperatures (°F)

Location of Station	Date	Max.	Date	Min.
Søndrestrøm	13 Aug	73.0	27 Aug	30.9
Base Camp	15 Aug	67.6	21 June	24.7
Intermediate Station #1	15 Aug	64.0	25 Aug	27.0
Intermediate Station #2	14 and 15 Aug	63.0	27 Aug	23.0
Edge of Icecap	15 Aug	57.9	27 Aug	23.0
Icecap	15 Aug	51.1	19 July	19.6
Dye I*	15 Aug	57.9	21 June	16.0

*data is from observations taken every six hours

TABLE 4. Mean maximum and minimum temperatures (°F)

		1963	1964
Søndrestrøm Air Base	max	69.8	73.0
	min	32.0	30.9
Base Camp	max	62.6	67.6
	min	28.4	25.0
Ice Edge	max	55.4	59.0
	min	23.0	23.0

The average diurnal temperature range at the various stations in the Tasersiaq area decreases with the elevation of the station, as shown in Table 5.

TABLE 5. Average diurnal temperature range in summer (°F)

Station	Clear days	Overcast
Base Camp	21.6	7.6
Intermediate #1	17.1	5.4
Intermediate #2	20.0	5.2
Ice Edge	16.2	4.7
Glacier	15.7	3.8
Dye I	10.1	5.6

The high range at Intermediate Station #2 on clear days is due to the low minimum temperatures there. These are caused by cold air draining from the Tasersiaq Glacier.

The wind pattern recorded at the ice edge shows that the cold air drainage coincides with the minimum temperatures. This phenomenon is especially prevalent during clear sky conditions.

The temperature ranges at the Glacier station and Dye I are quite different although the two stations are at approximately the same elevation. The difference arises from differences in the surface and terrain.

Glacier station is on a smooth, inclined surface that is snow covered all year. Dye I does not have a year-round snow cover and is on the summit of a mountain, Qaqatoqaq, which stands above the surrounding terrain. Insolation is less effective at Dye I, where the warmed air is readily removed, than at the Glacier station, where the area is not as open to air currents. Thus, the maximum temperatures at Dye I are usually lower than at Glacier station. Cold air at Dye I can drain down the mountain in any direction, so that minimum temperatures are not as low as they are at the Glacier station. There, cold air from the higher parts of the Sukkertoppen Ice Cap can drain to the station, and cold air can drain away only in one direction, northwest.

For overcast days the variation of temperature range with station elevation does not show any large abnormality. The range at Intermediate Station #2 does not deviate from the pattern. Dye I has a greater temperature range in these conditions than Glacier station. On overcast days, the wind is predominantly from the seaward side of Qaqatoqaq mountain. The air brought in by the maritime wind warms the Dye I area more than it does the Glacier station, which is not under the direct influence of maritime winds. At Dye I on clear days the wind is predominantly from the landward side.

Minimum and maximum daily temperatures at all stations were normally at about 0300 and 1500 hours respectively.

The temperature-frequency chart of 1500 hours (Fig. 2) shows the cooling effect of the snow cover at Glacier station, where the greatest frequency occurs around the freezing point, but at Dye I, the greatest frequency is at a slightly lower temperature, showing the effect of an open mountain top subjected to cooling winds. The land stations are all removed from the direct cooling effect of glacier snow and ice and the greatest frequency occurs in the 36° to 44°F temperature range.

At night the highest frequency for all the Tasersiaq area stations is around 30° to 34°F, and this includes Glacier station. This is a clear indication of the influence of cold air on temperature during the night (Fig. 2).

The temperature differences between Søndrestrøm Air Base (elevation 50 m) and Base Camp (elevation 723 m), for the few days when they had clear weather simultaneously, are: 0300 -1°F, 0900 -4°F, 1200 -2°F, 1500 -3°F, 1800 -4°F, 2100 -7°F, 2400 0°F.

PRECIPITATION

During the period 15 June through 31 August, the rain gauge at Base Camp collected 65 mm (2.55 inches) of water. In 1963, 41 mm of rain was collected during July and August, while during the same period in 1964 the amount was 56 mm, an increase of about forty percent over 1963.

In addition to a gauge which was read daily, Base Camp also had a totalizer rain gauge, which was read at the end of the season. The totalizer gauge, charged with kerosene to prevent evaporation, recorded only 32 mm over the season compared to 65 mm collected in the daily measured gauge. It is assumed that the daily measured gauge gives a more nearly correct total rainfall. The design of the accumulation gauge was based on those recently used by Dr. H. Hoinkes* in the Austrian Alps. He has also had difficulties with evaporation when kerosene was used, and now has found that liquid paraffin gives better results.

The precipitation collected in a similar totalizing rain gauge at ice edge station during the period of 24 July to 31 August was 10 mm (0.38 inches) so that the correct amount was probably about 20 mm (.76 inches). At the intermediate stations, small rain gauges were used which were read at frequent intervals (Table 6).

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*Personal Communication, Dr. Hoinkes.

TABLE 6. Precipitation (in inches) at intermediate stations

Date	June 15-21	June 22-28	June 39 to July 5	July 6-12	July 13-19	July 20-26	July 27 to Aug. 2	Aug. 3-9	Aug. 10-16	Aug. 17-23	Aug. 24-30
Base Camp	.12	.22	T	.56	.33	1.11	.15	.02	None	.04	None
Intermediate Station #1						.91	.13	.03	None	T	.08
Intermediate Station #2						1.02	.18	.04	None	.17	.01

The 1964 season was definitely wetter than the 1963 season. Not only was more precipitation received, but also, the total number of days with precipitation increased from 25 days in 1963 to 36 days for the same 84-day period of observation in 1964. Of these 36 days, 19 had measurable precipitation. From 9-30 June, there were 11 days with precipitation including 7 with measurable precipitation. During July there were 26 days with precipitation, of which 14 were measurable. In August, there were only 7 days with precipitation and 3 of these days received measurable amounts.

The heaviest rainfall occurred on 26 July during the passage of a weak depression. The winds on 26 July were of normal velocity but were heavy on the two previous days. Snow fell on 12 days, the greatest accumulation, 3 cm, being on 26 June 1964.

The accumulative precipitation chart (Fig. 3) shows that the precipitation profile along the mountainside does not follow the normal pattern for a mountainous area. Base Camp, for example, received more precipitation during the season than did Station #1 (141 m above base camp) or the Ice Edge station (369 m above base camp). There appear to be two reasons for this situation; the first is associated with the topography and its relation to wind direction, and the second with the thickness of the cloud layer from which the precipitation was derived.

Fifty percent of all moisture-depositing winds came from the southeast quadrant and three-fourths of them gave measurable precipitation. These winds from the southeast quadrant have easy access to Base Camp across Lake Tasersiaq; however, to the west of Base Camp the southeasterlies are forced upwards 550 m over the mountains, and thus release moisture by adiabatic cooling. These same winds supply moisture to Intermediate Station #2, which also has now 120 m higher terrain on its west side. Intermediate Station #1 and the Ice Edge station are both to the west of higher terrain and in a partial rainshadow. Moisture-bearing winds from the north have free access to all the stations. Westerly winds are partly blocked before they reach Station #2 and Base Camp. Only ten percent of moisture-depositing winds were from the west, and the precipitation was not in measurable amounts.

Several times during 1963 and 1964, rain fell from shallow clouds over the Tasersiaq Valley (Kosiba and Loewe, 1964). The tops of these clouds were often at the level of Station #2, which had some precipitation, while the ice edge had clear weather. On rare occasions the cloud top would be so thin that the clouds did not rise to the level of Station #1. As a consequence, Base Camp received more precipitation than the higher stations.

On some occasions in 1963 there was heavy precipitation at Base Camp while there was little or none at Søndrestrøm Air Base, 85 km away, and vice versa.* The same happened in 1964. On 24 July Søndrestrøm Air Base had 19.6 mm of rain while Base Camp had 1.8 mm. On 25 July Base Camp had 19.1 mm and Søndrestrøm had 3.0 mm.

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* IPS Report #11.

PRESSURE

Atmospheric pressure at Base Camp was recorded on a microbarograph, which was calibrated and checked against an aneroid barometer. The station pressure increased gradually from the lowest, 908.2 mb (26.82 inches), recorded on 24 June, to the highest, 945.5 mb (27.92 inches), recorded on 14 and 15 August. During the summer season, Søndrestrøm Air Base recorded its lowest pressure, 989.6 mb (29.22 inches), on 20 June, and the highest, 1031.9 mb (30.47 inches), on 12 August, with another high at 1031.1 (30.45 inches) on 14 August.

An hour-to-hour correlation of the pressure pattern at Base Camp with that at Søndrestrøm Air Base is not possible: at Søndrestrøm, reflection of direct sunlight from a steep rock face north of the station causes local heating and the development of a local and daily low pressure cell. The general increase and decrease of the pressure pattern shows a direct correlation between Base Camp and Søndrestrøm Air Base.

On 20 June 1964 a marked depression passed through the Dye I area. This depression was not observed at Søndrestrøm Air Base nor at Base Camp, which are both about 80 km from Dye I. This again indicates that the weather and climatic conditions may be very localized.

HUMIDITY

Atmospheric humidity was measured at Base Camp, Intermediate Station #1, the Ice Edge and at the Glacier Station (Table 7). The stations were equipped with hygrothermographs which were calibrated at Base Camp and checked with an Assmann psychrometer after installation in the weather shelter.

Table 7 shows that the relative humidity in the valley increases with altitude. This is the expected pattern when an air mass moves up a valley. However, during the week 20-26 July the pattern was disrupted. The humidity increased along the landbased stations but a decrease occurred at Ice Edge and Glacier Stations. During this week the prevailing wind was north and northwest while normally it is from the southeast. This change caused the air mass to move up the valley and to meet the katabatic winds from the Sukkertoppen Ice Cap. The air masses coming from the ice cap are heated adiabatically; the relative humidity decreases as the air descends and moves from the glacier station to the ice edge station. The similarity of the temperatures at the ice edge and at Intermediate Station #2 suggests that the air masses coming down from the glacier were forced to rise over air masses moving up-valley from Lake Tasersiaq.

TABLE 7. Weekly mean relative humidity

Date	22-28 June	29 June-5 July	6-12 July	13-19 July	20-26 July	27 July-2 Aug.	3-9 Aug.	10-16 Aug.	17-23 Aug.	24-30 Aug.
Base Camp	72	62	68	64	70	67	60	56	66	58
Interm. #1					80	76	70	61	76	65
Ice Edge					72	80	76	70	86	73
Glacier					68	81	80	72	86	69*

*from 6-day record.

GENERAL OBSERVATIONS

The summer season near Lake Tasersiaq is very short, lasting only a few weeks. During these weeks the temperature rises to 50°F or so and the weather is comparatively dry so that outside living is very pleasant and confortable. Most of the bogs and marshes in the area dry up, and the few remaining streams are from the ice cap and are silt-laden. The only remaining frest water is in kettle holes filled by seepage.

As in all mountainous areas, sudden wind and weather changes are experienced. The winds are influenced by topography and by the ice masses nearby. Each valley has its own wind system which can be completely different from that in a neighboring valley. In the Lake Tasersiaq area several valleys meet and the resulting wind system is complex. Flying conditions are difficult because of strong up- and down-drafts which are induced by the reflection of the incoming radiation by the steep cliffs along the north shore of Lake Tasersiaq. The air above the lake is super-heated and rises, and is replaced by cool, katabatically transported air, forming local circulating air currents.

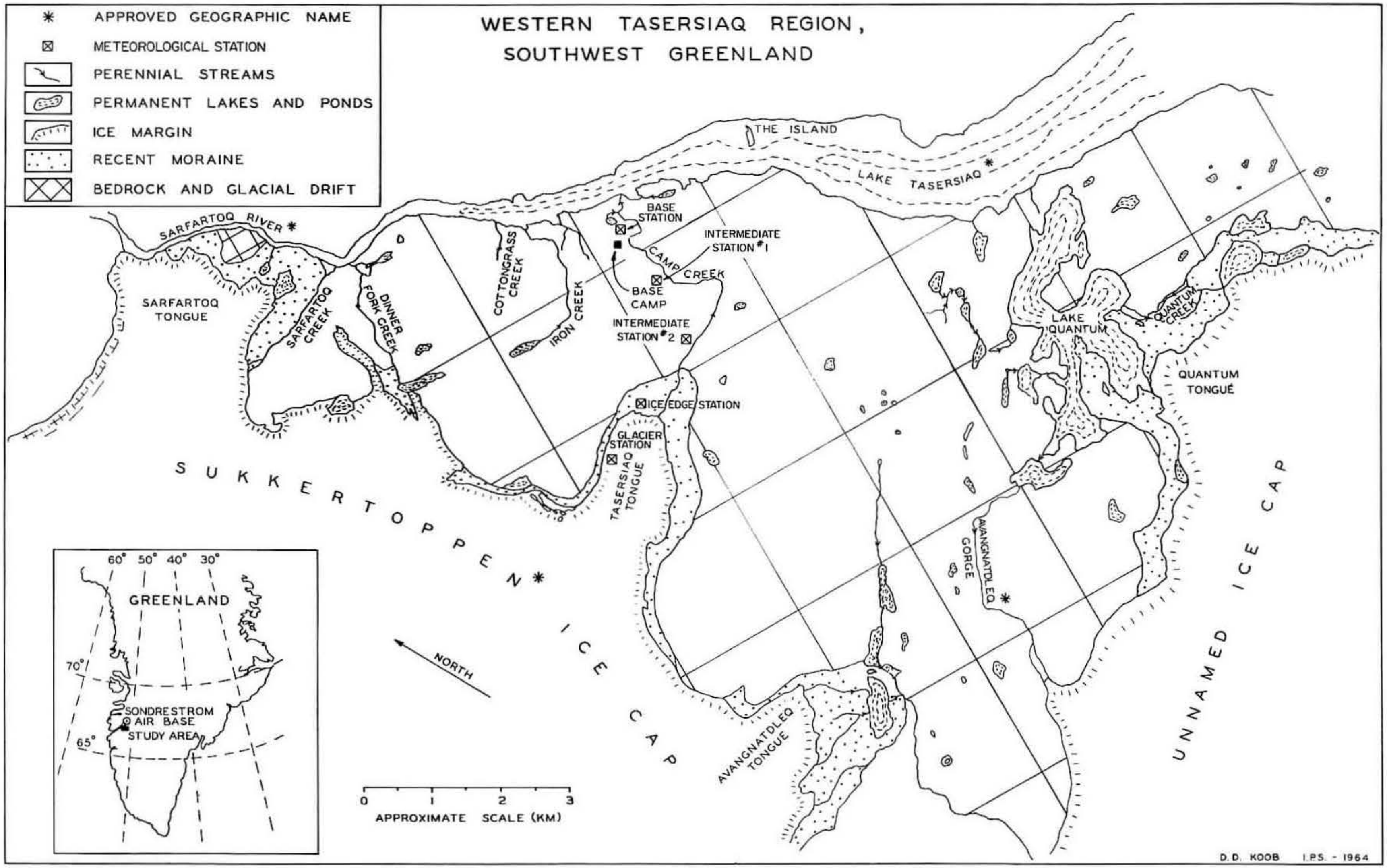
MISCELLANEOUS PHENOMENA

On 4 August 1964, a small twister was observed in the Lake Quantum area (Fig. 1). This twister did not reach the ground. Simultaneously three or four dark colored bands were observed in the air above the lake. They appeared as sine waves and stretched from north to south at an angle of about 15° above the horizon, as observed at Base Camp. Oscillations of this nature occur when two air bodies travel in opposite directions, one being above the other. This often happens when cold dense air draining from a cold surface, such as the Greenland icecap, meets a warmer air body. The cold dense air will then force the warmer air to rise over it resulting in the two moving in opposite directions. The oscillations occur in the shear zone between the two different airbodies. Southerly winds were gusting to 40 mph (18 m/sec) with an average wind speed of 25 mph, (11 m/sec) and it seems likely that the bands consist of dust picked up by the twister.

On three different occasions, 24 and 27 August and 2 September 1964 at 2300 hours, *aurora borealis* was observed. On 24 and 27 August it stretched as a single curtain in a northeast-southwest alignment. During the night of 2 September two bright curtains stretched in a north-northeast - south-southwest direction. Søndrestrøm Air Base reported *aurora borealis* on the 28th of August. It occurred from 2130 hours to 2230 hours and intermittently thereafter until after midnight.

REFERENCES

See composite list at end of report.



WESTERN TASERSIAQ REGION, SOUTHWEST GREENLAND
APPROVED GEOGRAPHIC NAME
METEOROLOGICAL STATION
PERENNIAL STREAMS
PERMANENT LAKES AND PONDS
ICE MARGIN
RECENT MORAINE
BEDROCK AND GLACIAL DRIFT
THE ISLAND
LAKE TASERSIAQ
SARFARTOQ RIVER
SARFARTOQ TONGUE
SARFARTOQ CREEK
DINNER FORK CREEK
COTTONGRASS CREEK
IRON CREEK
BASE STATION
INTERMEDIATE STATION #1
CAMP CREEK
BASE CAMP
INTERMEDIATE STATION #2
ICE EDGE STATION
GLACIER STATION
TASERSIAQ TONGUE
LAKE QUANTUM
QUANTUM CREEK
QUANTUM TONGUE
AVANGNATDLEQ GORGE
AVANGNATDLEQ TONGUE
SUKKERTOPPEN ICE CAP
UNNAMED ICE CAP
NORTH
0 1 2 3
APPROXIMATE SCALE (KM)
60° 50° 40° 30°
GREENLAND
70°
65°
SONDRESTROM AIR BASE
STUDY AREA
D.D. KOOB I.P.S. - 1964

Figure 1

FREQUENCY STATISTICS FOR THE PERIOD 20 JULY-31 AUGUST, 1964

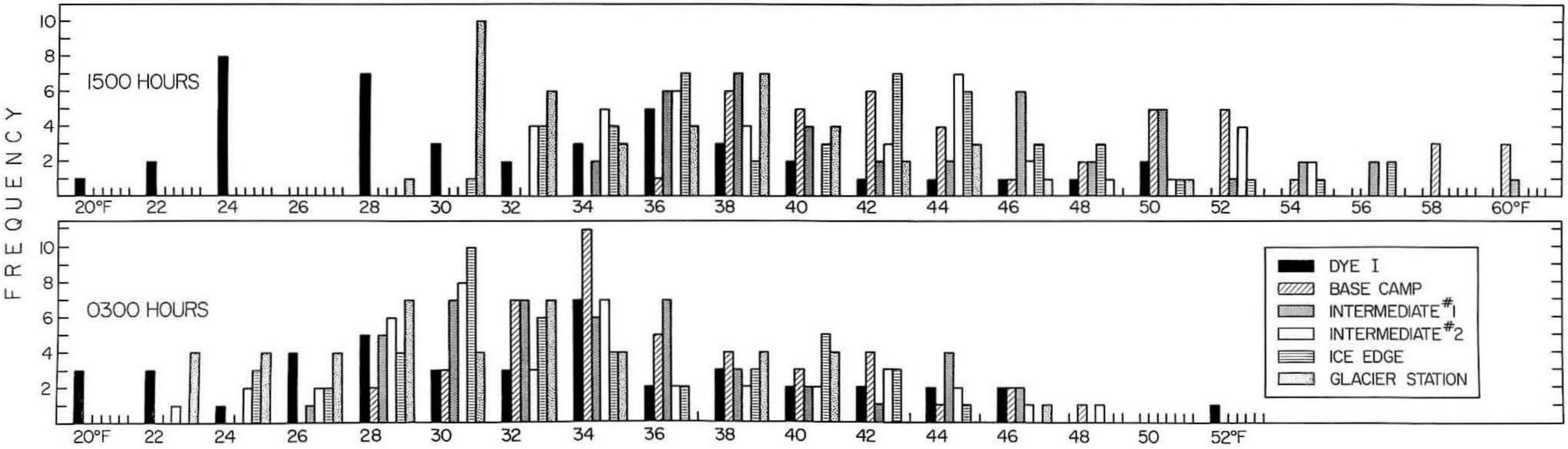


Figure 2

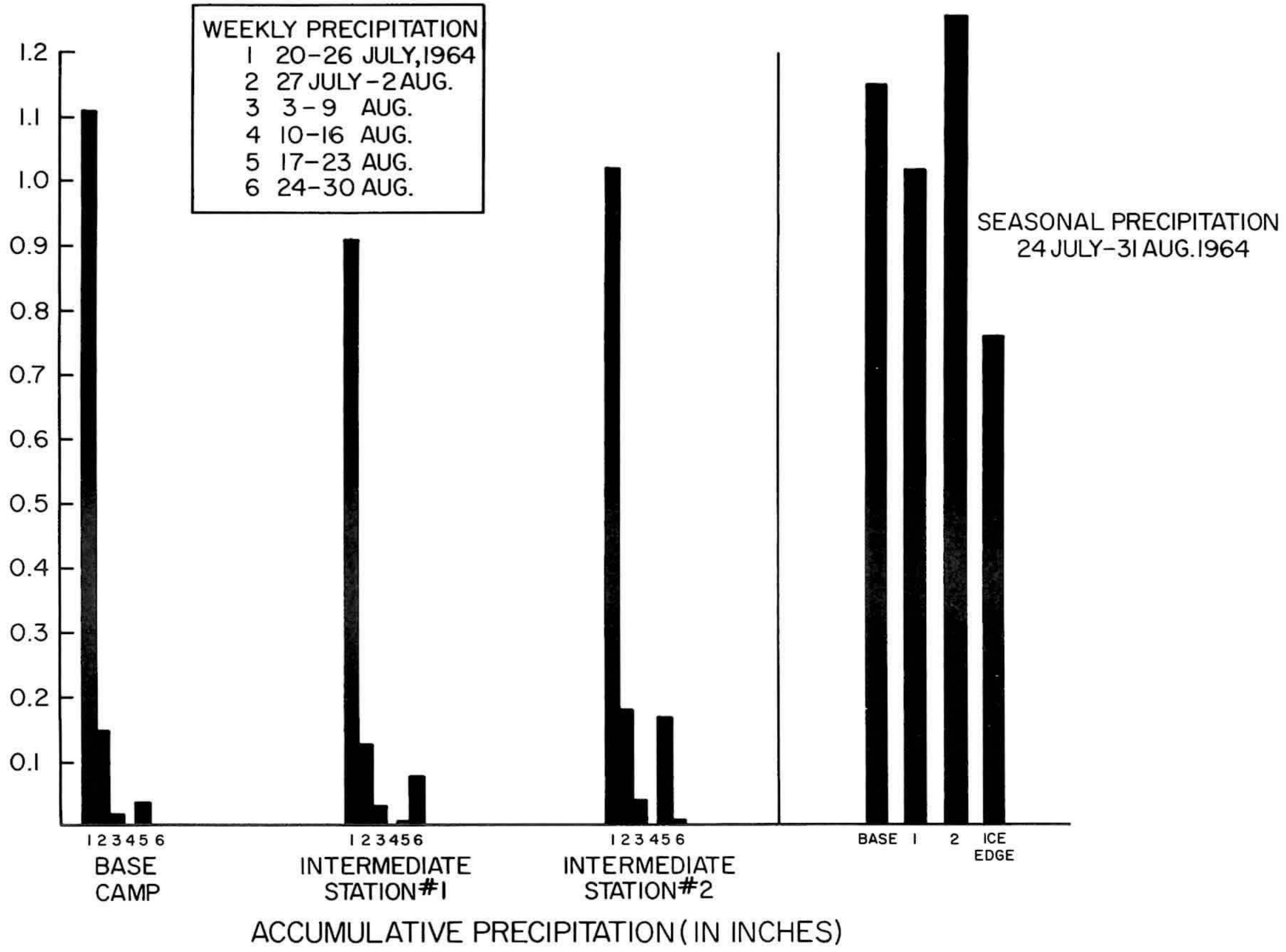

WEEKLY PRECIPITATION
1 20-26 JULY, 1964
2 27 JULY - 2 AUG.
3 3 - 9 AUG.
4 10-16 AUG.
5 17-23 AUG.
6 24-30 AUG.
SEASONAL PRECIPITATION
24 JULY-31 AUG. 1964
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1 2 3 4 5 6
BASE CAMP
1 2 3 4 5 6
INTERMEDIATE STATION #1
1 2 3 4 5 6
INTERMEDIATE STATION #2
BASE
1
2
ICE EDGE
ACCUMULATIVE PRECIPITATION (IN INCHES)

Figure 3

II. RADIATION OBSERVATIONS

by

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ABSTRACT

Between June and August 1964 observations of the duration of sunshine, of direct solar, of total and of net radiation were taken at the eastern foot of the Sukkertoppen Ice Cap. They show a relatively high intensity of incoming short-wave radiation, particularly with overcast sky, a small opacity of the air and on clear days in mid-summer over a sparsely vegetated surface a net intake of not less than 200 cal/cm^2/ day.

INTRODUCTION

In the Tasersiaq region of western Greenland in summer 1964, a meteorological station was established at a Base Camp near the shore of the big Lake Tasersiaq (Base) (66° 16' N, 51° 13' W) and at a nearby auxiliary station at the end of "Tasersiaq Tongue" (Glacier), (Loewe, et al., 1962; Kosiba, 1964). A few observations also were taken at a temporary camp at the edge of the Sukkertoppen Ice Cap (66° 24' N, 52° 22' W). In addition to the normal meteorological observations, (Kryger, this report) a number of instruments for the measurement of radiation in the atmosphere were available, mainly at the Base, either for the whole observation period, 9 June to 31 August, or at least for part of the time. They were the following; the names are those suggested for the International Geophysical Year. (Annals 1958):

(A). A Campbell Stokes sunshine recorder for temperate latitudes.

(B). One Eppley 180° pyranometer facing upward, and one facing downward, from 22 July.

(C). A bimetallic actinograph of the Robitzsch type (541) manufactured by Belfort Instrument Co. Another instrument of the same type (543) installed at the Glacier station from 13 July.

(D). One radiation balance meter (Funk 243), used with a 100 Ohm shunt.

(E). A Universal Actinometer Georgi, which can be used as a pyrheliometer, pyranometer, effective pyranometer and for measurements of albedo (Georgi, 1956).

Readings were taken for (B) with a millivoltmeter, for (D) with a potentiometer, and for (E) with a galvanometer with resistances of 20 Ohm and 8 Ohm. Unfortunately, no recorder was supplied for instruments (B) and (D).

SUNSHINE RECORDER

At Base, records of the duration of sunshine are available for the period 2 July to 31 August 1964. During this time, the broad-weather conditions varied very much. With the exception of the first three days and of the last day, July was very cloudy; August on the other hand had a considerable number of completely or nearly cloudless days.

At Søndrestrøm Air Base July was particularly cool and had nearly four times the normal precipitation (US Weather Bureau, 1964). The Base data is shown in Table I which gives, for two-hourly intervals, the average fraction of the time with sunshine, the duration of sunshine in hours for half-days, and the proportion of actual to possible sunshine. The last is the percentage of locally possible sunshine, not of that with a free horizon. As no measurements of the elevation of the actual horizon have been made, the possible duration of sunshine had to be estimated from the records of cloudless days.

EPPLEY 180° PYRHELIOMETER

The Eppley 180° pyrheliometer was to serve as standard instrument for total (sun & sky) radiation. But as no recorder was available, only a small number of readings was taken, starting with 10 July. Total radiation on an horizontal surface with clear sky at midday reached 1.14 cal/cm^2/min in the middle of July (height of the sun 45°), 1.04 ly/min at the end of the month (42°), and 0.91 ly/min in the middle of August (38°). This latter value is in good agreement with those found in 1938 at the same time of the year at about the same level on the other side of the Sukkertoppen Ice Cap (Etienne, 1940). From the small number of observations with cloudless sky at different heights of the sun which include only one morning observation, the total radiation between the solar heights of 15° and 45° can be represented by $0.70 + 0.028\ (h - 29)$ ly/min, with a probable error of $\pm\ 0.04$. These values are somewhat higher than those resulting from Albrecht's empirical formula (Albrecht, 1940).

At the place of observation, the surface consisted of a mixture of gravel and sand with little low vegetation. Numerous observations with clear sky gave a mean albedo of 17% with little variation. Possibly towards the end of the period, after a dry and sunny spell, the albedo was slightly higher.

TABLE 1. Sunshine at Tasersiaq Base, Summer 1964

	Hour											
	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	Morn.	Aft.	Day	%
July	.24	.40	.34	.42	.42	.31	.21	.11	2.77	2.08	4.85	32
Aug.	.24	.67	.77	.80	.76	.71	.68	.16	4.71	4.62	9.33	70
Sum.	.18 (5-6)	.54	.55	.61	.59	.51	.45	.14	3.75	3.37	7.12	51

BIMETALLIC ACTINOGRAPH

At the Base, the total radiation of sun and sky from 9 June to 31 August 1964 was recorded by a bimetallic actinograph of the Robitzsch type manufactured by the Belfort Instrument Co.. The same instrument had already been used during the summer of 1963 (Kosiba and Loewe, 1964). Another instrument of the same type was used from 13 July to 31 August at the Glacier station. The instrument has one blackened strip exposed and one strip covered. Its sensitivity is very satisfactory. The instrument is supplied with charts uniformly divided into cal/cm^2/min (ly/min). No special calibrations for high and low sun and for direct and diffuse radiation are available. It is, however, likely from the study of instruments of similar construction that the sensitivity under varying conditions is far from uniform.

There are a limited number of simultaneous observations under cloudless sky with the Eppley instrument which may be accepted as approximately correct, and a considerable number of such with the Georgi instrument used as a pyranometer. Unfortunately, as will be shown later, the calibration of the Georgi instrument is itself doubtful, and the data of the bimetallic actinograph cannot be checked in this way.

As to the Eppley instrument, its sensitivity appears to remain constant with varying solar heights, at least down to 15° (Hanson, 1960, Fuquay and Buettner, 1957), and it might be permissible to find the calibration factors for the Belfort instruments for different heights of the sun by comparison with the Eppley, at least for clear sky. Comparison of the absolute values of the Belfort instrument at the Base (541) with the Eppley suggests that, on the average, the Belfort instrument reads about 6% too high. In first approximation the Belfort data would probably be improved if reduced by 6%. But a further consideration shows that the relation between the Belfort and Eppley instruments varies strongly with the height of the sun (Mőrikofer and Thams, 1936; Stapf, 1938). Very approximately the relation between the Belfort and Eppley readings can be given as Belfort/Eppley = 1.525 - 0.015 h, with h the height of the sun in degrees. From this one obtains the correction c_B to be applied to the readings B of the Belfort instrument 541;

$$c_B = \frac{B(.015\ h - .525)}{1.525 - .015\ h} .$$

The Belfort instrument reads too high for low positions of the sun and too low for high positions. The corrections are given in the following table.

TABLE 2. Corrections to Belfort Actionograph 541

Height of sun°	15	20	25	30	35	40	45
Correction	-.23	-.18	-.13	-.07	.00	+.08	+.18

There is, moreover, a considerable discrepancy between the readings of the two Belfort instruments. This had already been noticed in 1963. Both instruments were simultaneously checked with the same exposure for 8 days in June at the Base and again for 5 days at Columbus. These comparisons showed:

(a). For averages of the whole day, instrument 543 reads about 6% lower than instrument 541. As 541 was about 6% higher than the Eppley instrument, 543 would be close to the Eppley value.

(b). The simultaneous proportions of the two instruments at a certain height of the sun during morning or afternoon are not significantly affected by the absolute amounts of the incident radiation. This shows that the sensitivity of the instruments at a given angle of incidence is not differently affected by the intensity of the incident radiation.

(c). If, however, morning and afternoon values at the same height of the sun are compared, the picture becomes very different. It has already been noticed in 1963 when 541 was used at the Base and 543 at the Glacier, that 543 showed a maximum of radiation at about 2 p.m. when the sun was about 4° lower than at midday. It had then been tentatively suggested that this might be due to radiation reflected in the afternoon from the high parts of the glacier nearby. But the comparison at the Base in 1964 showed that the proportion of the indicated total radiation of 541 and 543 was 1.20 in the morning and 0.96 in the afternoon. At Columbus, the proportion 541/543 was 1.22 in the morning and 1.01 in the afternoon, nearly identical with Base. For early and late hours, the discrepancy is slightly bigger, before 10 a.m. 1.28 and after 4 p.m., 1.01. Inspection of the instruments revealed that the receiving strip of instrument 543 was not horizontal but in the position used was lower at the western side than at the eastern side. Bimetallic actinographs are very sensitive to inclination of the strips, (Mörikofer and Thams, 1963; Stapf, 1938), and the shift of the maximum to 2 p.m. and the prevalence of radiation in the afternoon in instrument 543 can be explained in this way. But it is not known at what time the bending of the support of the bimetallic strip occurred and whether it occurred instantaneously or progressively.

If it is supposed that the instrument 541 at the Base reads consistently 6% too high and that the readings of 543 at Glacier have to be increased by 11% in the morning and to be decreased by 6% in the afternoon as suggested by simultaneous values of 543 and the corrected 541, we get, with a considerable amount of uncertainty, the following mean total radiation for the months June, July and August 1963 and 1964 in central western Greenland. The values of incoming radiation are conservatively estimated; the true values might be rather somewhat bigger than lower.

TABLE 3. Total radiation of sun and sky
(cal/cm^2/half day and/day)

	Base			Glacier		
	a.m.	p.m.	day	a.m.	p.m.	day
July 1963	220	270	490	210	290	500
Aug. 1963	160	210	370	160	270	430
June 1964	240	290	530	---	---	---
July 1964	210	210	420	230	210	430
Aug. 1964	190	200	390	170	230	400

At the time of highest position of the sun, the daily radiation from sun and sky on an horizontal surface can reach 680 langley. If it is supposed that the instruments are equally sensitive to direct and diffuse radiation (this holds only very approximately) the proportion of incident radiation with overcast and clear sky is in 1964, 38% at the Base and 46% at the Glacier station. This is in good correspondence with the result of observations during 1963 (Kosiba and Loewe, 1964). It shows again that the clouds at the latitude of the polar circle in western Greenland have a smaller density than in lower latitudes. As the instruments used are likely to be more sensitive for diffuse than for direct radiation, the proportion will probably be really somewhat lower.

RADIATION BALANCE METER

The radiation balance meter worked very satisfactorily until damaged by an accident on 31 July. According to the calibration supplied by the manufacturer, the Funk instrument is practically equally sensitive for short-wave and long wave radiation. The temperature coefficient of the instrument is not known. In June and July about 260 observations were taken, mostly hourly observations during day and night. Unfortunately, cloudiness during the period of observation was very variable, and it is hardly possible to provide representative data for whole days. During the second half of June, the radiation economy over a gravel surface became, on the average, positive at about 0400 and remained so until 2030 hours. Over a surface of clean white snow at a height of 1100 m the radiation economy already became negative at 1630. At the Base, near the summer solstice during the midday hours with sunshine and little cloud the net radiation reaches .38 to .40 ly/min over a surface of gravel, sand and a few plants; near midnight, the net loss of radiation is about -.60 ly/min. Over a surface of clean snow, the maximum net intake during such days was near .15 ly/min, the loss at night -.10 ly/min. On clear days in mid-summer the net radiation gain of a surface of albedo 17% is of the order of 200 ly/day, a value that seems rather low (Ambach, 1963).

UNIVERSAL ACTINOMETER

Georgi's Universal Actinometer proved very suitable for expedition conditions. It is compact and can easily be transported and be put into operation. The changes between the different uses as pyrheliometer, pyranometer, effective pyranometer and albedometer are accomplished easily.

a) Calibration for direct solar radiation.

The calculations of direct solar radiation with Georgi's instrument seemed to give unreasonably high intensities if the calibration factors supplied with the instrument were used. No observations with another instrument are available. It had been hoped that a new calibration would be made after return; but the instrument was damaged during the transport to the place of recalibration. Therefore, a comparison had to be made with pyrheliometer observations taken in 1938 on the other side of the Sukkertoppen Ice Cap, (Etienne, 1940) and on the inland ice 380 km further north in 1959 (Ambach, 1963). Etienne's Glacier Camp at 400 m is in a situation comparable to the Base on Tasersiaq; Etienne's Igdlo Station at 1400 m and Ambach's Camp IV at 1000 m correspond to the briefly-occupied station on the northern edge of the Sukkertoppen Ice Cap. A comparison shows that the pyrheliometric values obtained with the Georgi instrument should be reduced by 20% to become comparable with the earlier observations. It may be supposed that the same reduction applies to the observations of direct solar radiation behind clear glass and those behind red (RG 2) and yellow (OG L) filters. (After the completion of this paper, information was received from Dr. Georgi that the calibration factors were 16% too high).

b) Calibration for total radiation.

A considerable number of observations of radiation from the upper and lower hemispheres have been taken, with both a glass (short-wave) and lupolen (all-wave) cover. A few observations taken simultaneously with those of the Eppley 180° pyrheliometer, which was to serve as a standard instrument, suggested again that the calibration for total radiation supplied with Georgi's instrument gave values that were considerably too high. The comparison showed that the calibration factor of Georgi's instrument should be reduced by 28%; but, as only five simultaneous observations under stable conditions are available, not much reliance can be placed upon this result. It will be noted that this reduction is bigger than that found for the measurements of direct solar radiation.

A further way of checking the calibration factor for total radiation is to use a shadow ring to block the radiation from the sun. The difference between the readings with and without the ring represents the radiation from the sun. This can be compared with the value resulting from a pyrheliometer measurement reduced to the value incident upon a horizontal surface by multiplication with the sine of the height of the sun. Apart from the influence of the shadow ring by the additional obstruction of sky radiation both methods should give the same value of the intensity of direct solar radiation upon the horizontal surface. Unfortunately, this is not realized with the calibration factors supplied. The pyranometer readings with the use of a shadow ring give systematically higher values than the pyrheliometric measurements of solar radiation. As the latter turned out to be already 20% higher than comparable values (Etienne, 1940; Ambach, 1963), the pyranometer readings appear to require a reduction of 30% to give values consistent with the reduced pyrheliometer values and with other observations in similar situations. This is in satisfactory agreement with the direct comparison between the five simultaneous observations with the Eppley and Georgi pyranometers.

c) Results from Georgi's Universal Actinometer.

As the pyrheliometer observations had to be corrected with the aid of observations in similar locations, it does not seem worthwhile to discuss them in detail. In any case the variation of the solar radiation with height of the sun and amount of air passed by the solar beam is in very good agreement with the other observations as shown in Table IV.

TABLE 4. Mean solar radiation (ly/min)

	Height°						
	10	15	20	25	30	35	40
Base	.79	.97	1.10	1.18	1.24	1.32	1.38
Glacier Camp (Etienne)	.80	.99	1.12	1.19	1.26	1.30	1.33
Snow Base	.94	1.10	1.23	1.30	1.35	1.40	1.44
Igdlo Camp (Etienne)	.97	1.11	1.23	1.30	1.34	1.38	1.42

It might be expected that the turbidity factor can be reasonably determined from these reduced data. The mean "extrapolated turbidity factor" (Feussner und Dubois, 1930, Annals 1958) at the Base with a pressure of 920 mb is 2.40; a small number of observations at the Snow Base with mean pressure 860 mb gives 2.20. This is in reasonable agreement with the observations of Etienne (1940) and Ambach (1963).

Independently of the somewhat doubtful absolute values of the solar radiation, the measurements with the yellow and red filters allow determination of the "true red" and "true yellow" proportion for different air masses passed. Table V gives the result of a rather small number of observations. The "true red proportion" for a pure dry atmosphere, for pure atmosphere with 2.5 cm precipitable water corresponding to about 6 1/2 mb of vapor pressure at the surface, and Ambach's true red proportions have been added (Ambach, 1963). The result is nearly identical with Ambach's values and fits very satisfactorily with an atmosphere with a vapor pressure of 6 1/2 mb without dust, which approximates the conditions in Greenland.

TABLE 5. Yellow and red proportions and air mass

	Mass									
	1.0	1.25	1.50	2.00	2.5	3.0	4.0	5.0	6.0	8.0
yellow %		77	78	80.5	82.5	84	85.5		88	90.5
red		62	63	65.5	67.5	69	72.5		77	80.5
red,pure,dry		65.5	66.5	68.5	70	71.5	74		78	81.5
red,pure, 6-1/2 mb	63					69		74		
red, Ambach			64	65.5	67	69	71.5		76.5	80.5

A considerable effort has been made to determine the turbidity coefficient B' from the difference between the total and red radiation; but the data do not appear to be accurate enough for a meaningful result.

The uncertainties of the calibration factors do not warrant a detailed treatment of the absolute values of total radiation. Roughly, the total radiation with clear sky is, in cal/cm^2/min, $I = 0.024\ h$, with h the height of the sun in degrees. Apart from a possible higher sensitivity of the instrument for diffuse radiation, the proportion of total radiation with overcast and cloudless sky is not affected by the absolute values. For solar heights of more than 35° corresponding to less than 1.6 air masses, the radiation from overcast is about 40-45% of that from cloudless sky. This corresponds well with the result of the observations in 1963 (Kosiba and Loewe, 1964). It is a rather strange fact that the proportion of overcast to clear sky radiation increases quite systematically with increasing height of the sun. At a height of 15° it is only one third of the proportion at 45°. This has not been noticed at other stations in high latitudes (Liljequist, 1956). The reason might be that with high sun some direct radiation penetrates the rather thin cloud cover; but the number of observations is too small to draw further conclusions.

Some observations of albedo were taken with Georgi's instrument. With the sun shining through an altostratus cover at a height of 38°, a wet snow surface had an albedo of 70 - 75%, a bare sand and gravel terrace 26%, a surface covered with dry grass 17%, a cover of cranberries 15%, and a shallow seepage pool with a dark bottom 5%.

Some observations have been made using, in the pyranometer, a lupolen cover which is transparent for long-wave radiation, instead of the glass cover. Most of the observations refer to periods with variable cloud conditions. Those with a nearly clear sky suggest a heat loss of the radiating plate towards the sky of -.15 to -.10 ly/min. This appears in reasonable agreement with the data from the net radiation instrument. Detailed discussion is not warranted because the temperature of the radiating plate could not be determined.

From the difference between the values measured with Georgi's instrument with a glass cover and a lupolen cover the long-wave radiation from the atmosphere can also be calculated if the temperature of the receiving black surface is known. This had to be estimated. The mean atmospheric radiation then turns out to be of the order of 0.45 ly/min.

CONCLUSIONS

The observations show that, during the summer months, the radiation at the border of the Sukkertoppen Ice Cap is as would be expected in a relatively dry climate near the polar circle. The strong radiation from sun and sky, even under cloudy conditions, together with the long duration of sunshine allow rather well-developed plant cover to extend to appreciable heights above sea level.

REFERENCES

See composite list at end of report.

III. MASS-WASTING IN THE LAKE TASERSIAQ AREA

by

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ABSTRACT

The ice-free Lake Tasersiaq area, marginal to the Sukkertoppen Highland Ice is underlain by gneiss and jointed granite which have only a thin covering of ground moraine.

With local exceptions, patterned ground is not well developed. Solifluction lobes occur on both valley slopes, but solifluction sheets are restricted to the gentler northeast-facing slope. Many sheets and lobes show an imbricate arrangement of boulders at their frontal margins. These features appear to be of rather recent age. Slump features which show imbrication of boulders on their frontal margins are common, both as recent and "fossil" forms.

Micro-mudflows and debris slides are the most active features of the area in terms of volume of material moved. The amount of soil displaced at any one time by a single flow ranges between a few hundred cubic centimeters and several cubic meters. There is evidence of large mudflow activity in the past, but no recent activity was observed.

Water, both under pressure and on the surface, and wind are important contributors to mass-wasting in the Tasersiaq area.

Qualitative and quantitative observations of mass-wasting in the valley suggest that the processes are operating at a rate two to three times faster on the northeast-facing slope than on the opposing valley slope.

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IV. SOILS OF LAKE TASERSIAQ AREA, GREENLAND

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DESCRIPTION OF AREA

Lake Tasersiaq area is a portion of the ice-free foreland marginal to the Sukkertoppen Highland Ice. Bounded by latitude 66°24' and 66°40' north and longitudes 51°19' and 51°30' west it is situated about 90 Km south-southwest of the Sønderstrøm Air Force Base and is located in the Sukkertoppen Kommune. The total area investigated covers approximately 100 sq. km.

Bedrock Geology

The bedrock geology of the area covered in this report has not been investigated in detail. Treves (1962 and 1964 in preparation) has done detailed geologic mapping at the east end of Lake Tasersiaq.

The bedrock is composed of steep to vertically dipping Precambrian gneisses with variable amounts of included schist. The oldest gneiss at the east end of the lake is a grey biotite or hornblende gneiss. In places it is a strongly contorted migmatite containing inclusions and schlieren of biotite schist, hornblende schist and amphibolite, (Treves 1962). This statement also describes the rocks that make up the precipitous ridge which parallels Lake Tasersiaq on the northeast.

Lake Tasersiaq represents a structural discontinuity between the gray paragneiss (Treves, 1962) and a similar gray paragneiss which makes up, at least in part, the dip-slope hills on the southwest, and which is extensively intruded by red granite and/or granite gneiss. The gneiss grades (?) across a structural depression into red granite and granite gneiss with minor inclusions of gray paragneiss. This last rock type supports the more rugged topography up to the Sukkertoppen Highland Ice.

The gneisses on both sides of Lake Tasersiaq are intruded by large ultrabasic dikes of considerable lateral extent. Red feldspathic dikes are common, and intrude the paragneisses on the southwest side of Lake Tasersiaq.

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In many areas the original bedding is preserved and dips range between 20° and 65° to the northeast. At least one prominent set of joints characterizes extensive areas of this igneous-metamorphic complex, one set trending northeast-southwest and the other, northwest-southeast. This joint set controls the major drainage network of the area to a large degree.

Surficial Geology

Details of the surficial geology of the Lake Tasersiaq area have been outlined by Crowl and Goldthwait (1963) and will be given here in general terms as background.

Broadly classified the deposits are: (1) ground moraine or till and end moraine related to Wisconsin or earlier glaciation; (2) Kame terraces and outwash representative of several minor glacial advances or still-stands during retreat; (3) recent end moraine and outwash, close to and related to, present glaciers.

Almost the entire ice-free area is blanketed by bouldery, sandy ground moraine and till, except where it has been removed from the steeper slopes by mass-wasting and running water. The slopes, particularly on the southwest side of Lake Tasersiaq are complicated by a series of discontinuous kame terraces up to 100 meters or more above the present lake level. Similar terraces on the opposing slope are less well preserved and do not occur as high up on the slope, either because they were never deposited or have been removed by mass-wasting subsequent to ice retreat. Many of these terraces have a veneer of ground moraine and may display rock rampart fronts.

Extensive areas of the valley bottom at this, the west end of Lake Tasersiaq are occupied by flat-topped outwash and/or kame terraces to an elevation of 19 meters above present spring lake level. According to Crowl and Goldthwait (1963) these deposits are related to a late phase ice tongue. The deposits are horizontally bedded or display a gentle dip toward the surrounding high ground. Most are sparsely covered with sedges and grasses and have a wind stripped surface of lag gravel.

Moraines of uncertain age and affinities block the head of a dry valley and are bissected by Camp Creek (Fig. 1 in Part I). Moraines and outwash associated with present day glaciers cover only a small percentage of the ice free area. The moraines are ice cored and while topographically impressive are of little importance to this study except to show that the original materials are coarse textured with a large content of stones and boulders and that the fines are slightly calcareous (see Table 3).

Topography

The foreland area just east of the Sukkertoppen Highland Ice is characterized by long asymmetrical valleys, bounded by precipitous escarpments on the northeast and dip-slope hills on the southwest. Most are occupied by underfit streams and/or pater noster lakes.

Highland elevations which range around 500 meters near the head of Søndrestrøm Fjord reach 1100 meters in the Lake Tasersiaq area.

The most pronounced topographic feature of the area, aside from Lake Tasersiaq itself is Avangnatdleq Gorge along which is displayed some of the most impressive scenery of the area, particularly on the south side where outlet glaciers of the inland ice pass around imposing half-domed peaks as they flow into the gorge. The gorge and its westward extension, Evighead Fjord follow the northeast-southwest joint set.

Lake Tasersiaq is approximately 60 kilometers in length, empties to the northwest through a deep, narrow gorge into the Sarfortok river which, in turn, empties into the Søndrestrøm Fjord.

Repeated Pleistocene glaciations have sent tongues of ice down the major drainage lines and the inland ice completely covered the area at least once and probably several times. Changes wrought by the ice are not as pronounced as might be expected. The glaciers worked on a landscape with a well established drainage pattern, a pattern most likely sculptured by streams long before the Pleistocene. Glaciations have modified the landscape, widening and in some cases, deepening valleys, oversteepening escarpments and in the lower reaches of Lake Tasersiaq sculptured gneissic outliers into Roches Montonnees. Moraine deposition in one case blocked and diverted Camp Creek. Kame deposition on the lower portions of the hillsides has imparted a benched appearance to the slope profile.

The uplands appear to be little modified by glaciation. Till cover is thin or absent. These surfaces must have undergone scour by a thinner, slower moving ice sheet. According to Goldthwait and Crowl (1963) the last ice advance to be of major significance, at least in the lowlands, was approximately 9000 years B.P.

Climate

According to observations made in 1963 (Brecher and Kryger 1963) the general climate of Tasersiaq area is characterized by cold wet spring and autumn and a short dry summer. Wind speeds of more than 9 m/sec. were common while the highest velocity recorded was 18.5 m/sec. The prevailing winds are in the southeast quadrant, with the strongest winds from the south and southeast.

A total precipitation of 47 mm. was recorded. Of this total 32 mm fell between 26 June and 18 July and 9 mm between 24 August and 1 September. No precipitation was recorded from 19 July to 2 August. Snow flurries occurred in all months. Judging from snowbank accumulations winter snowfall appears to be moderate to light. The strong southerly winds form large drifts on the north- and northwest facing slopes, many remaining throughout the summer. These strong winds keep the terraces relatively clear of snow.

Observations of temperatures made during the months of July and August have been summarized by Kosiba and Loewe (1964). As shown in Table 1, the temperatures are low but show appreciable fluctuations. These observations also indicate that the temperatures near the Tasersiaq Tongue glacier at an elevation of 1040 m are noticeable lower than those recorded at the Base camp having an elevation of about 680 m.

TABLE 1. Mean and mean maximum and minimum temperatures in °C July and August 1963 recorded at Base Camp and at Tasersiaq Glacier

Station	Month	Mean	Mean Max.	Mean Min.
Base	July	6.5	10.4	2.4
Glacier	"	3.8	6.8	0.4
Base	August	7.4	11.7	3.6
Glacier	"	4.5	7.8	1.3

Soil temperatures observed during the summer of 1963 show appreciable variability, the soils of the well-drained sites are noticeable warmer than those that are wet or very poorly drained. Insulation due to the surficial layer of organic matter and the probably lower temperatures of the waters emanating from the melting snow banks appear to be the contributing factors. Observations made at two sites at end of July are recorded in Table 2 as examples of these differences in soil temperatures.

TABLE 2. Comparison of soil temperatures recorded on 29 and 30 July at a well drained and a very poorly drained site

Site	Temperature (°C)		at depths of
	5 cm	15 cm	30 cm
Well drained	13.1	8.5	6.5
Very poorly drained	6.5	5.5	4.7

The substrate of all soils is permanently frozen. In well drained soils the depth to this permanently frozen zone in the latter part of the summer is about 1.5 to about 2 meters. It is appreciably less in the soils of the wetter sites.

Vegetation

McCormick in Loewe *et al.* (1962) described the vegetation of the region as "a mosaic of Arctic steppe, shrub tundra, and wet meadow tundra and lichen encrusted rock fields."

The south-facing slopes have an Arctic steppe vegetation composed of the following dominants: *Calamagrostis*, *Kobresia*, *Poa*, *Hierochloe*, and *Carex*. This flora alternates and is interspersed with dense stands of *Betula nana*-*Empetrum nigrum* association, *Salix glauca*, or *Vaccinium uliginosum*. The *Betula*-*Empetrum* association is common in the dryer boulder fields.

Vaccinium outlines the shallow, moderately to poorly drained areas. Salix is common as isolated shrubs in boulder fields and on well drained hillsides.

The north-facing slopes are, according to McCormick, occupied by mixed stands of Luzula, Carex, and in the moist places by Vaccinium. Cassiope, the largest component of the vegetation, exclusing Carex, can be found on all areas of the slope except the very wettest and occurs in almost pure stands on the north-facing outwash slopes. A relatively minor constituent in the total vegetation, but none the less ubiquitous, is Lycopodium selago.

The flat areas, particularly the valley bottom kame or outwash terraces are covered with communities similar to those of the north-facing slope with the addition of grasses, principally Agropyron geradi.

Carex aquatilis and mosses are the predominant constituents of the vegetation prevailing in wet and very poorly drained sites.

SOILS

A variety of soils intermingled with patches of rockland especially around the periphery occupy the land area investigated. The rockland ranges from nearly level to mountainous in relief and it may be nearly bare or it may be strewn with rocks of various sizes, many being large boulders. Fines where they do occur on the rockland are thin and patchy and are usually of a coarse sandy texture. The differences amongst the several kinds of soil are due primarily to difference in composition and stability of parent materials and in soil moisture environments. The latter factors are related to such features of topography as length, gradient, and shape or form of the slopes, the direction of exposure to insolation and to winds, and the microrelief of the surface. Vegetative cover, especially its composition, is likewise an important factor, but it too appears to be related closely to the moisture environments of the soil.

Soil parent materials

Very stony or bouldery sandy till provided the original source of parent materials in the area and it consitututes the materials from which most of the well or excessively well-drained soils have been derived. This till exhibits considerable uniformity throughout the area although it has been deposited by glaciers entering the area from several directions. The fines of the till are olive gray (5Y 5/2) loamy sand or sandy loam. They are slightly calcareous with the calcareous fraction being predominantly dolomitic.

The materials of the outwash and/or kame terraces are composed of sands and gravel, the latter component being rounded or subrounded pebbles or cobbles of the rocks common to the area. Although these materials have had their origin in the glaciers, the fines apparently have been subjected to considerable sorting since their mechanical composition is almost entirely sand and they are not calcareous.

Appreciable sorting of upland till material has been noted along sections of the upland slopes where they serve as passage ways for run-off or water of the melting snowbanks. Such materials contain appreciable quantities of silt.

Data pertaining to the mechanical composition and some chemical properties of the fines are given in Table 3 for selected samples of these materials. Numbers 16394, 16396, 16399, and 16346 are samples of till or soil parent materials taken respectively from Quantum, Safartoq, and Tasersiaq glaciers and from a deep sampling of an upland soil profile about 1 km south of the Base Camp. Samples 16237, 16248, and 16359 are examples of the outwash and/or kame terraces, while numbers 16224, 16364, and 16367 represent the water sorted materials of the slopes.

It was noted at several locations that in case of the well-drained upland soils of the lower elevations, the upper part of the soil profiles were more silty to an appreciable degree. This suggests that there may have been some loessal deposition on the surface of the till.

Very limited areas of medium- or fine-textured materials, apparently of lacustrine origin, were noted at several locations. Because of their very limited extent, soils derived from such material have not been separated.

Soil moisture environments

Soil moisture environment refers to the kind of moisture regime that prevails in a soil during the warm season, i.e., during the time when the temperature of the entire soil is above freezing. Some soils are saturated or even submerged while others may be subject to excessive moisture conditions only intermittently. Still others may be relatively free from such conditions and in some there may be a scarcity of moisture holding capacity. Excessive dessication by wind may also contribute to a scarcity of soil moisture at some sites.

Soil moisture environments are reflected in such morphological features as color and the quantity of organic matter accumulations. Water logged conditions, because of inadequate aeration, produce gray colors and may favor considerable accumulation of organic matter. Intermittent periods of excessive moisture lead to mottled colors in which gray is generally intermingled with various shades of brown. Various shades of brown colors alone are associated with good aeration and oxidation such as occur under adequate but yet not excessive moisture conditions. Scarcity of adequate moisture is indicated by absence or only weak development of soil colors.

Seven categories of soil moisture environments were recognized in the area on basis of color and organic matter accumulations. Each of these categories is defined below and is referred to as a soil drainage class following in general the concepts outlined in Soil Survey Manual (Soil Survey Staff 1951).

TABLE 3. Mechanical composition and some chemical properties of the fines* of parent materials

Sample No.	Depth of sample, cm.	Sand,** %	Silt,*** %	Clay,**** %	pH	$CaCO_3$ Equiv., %	Calcite %	Dolomite %	Free Fe_2O_3, %
				Till					
16394	-	77.5	21.5	1.3	8.5	0.6	0.3	0.3	0.4
16396	-	80.1	19.4	0.5	7.9	1.0	0.3	0.6	0.6
16399	-	69.7	26.4	3.9	8.1	1.3	0.5	0.7	0.7
16346	117-125	70.5	24.8	4.7	8.3	1.1	-	-	0.4
				Outwash and/or kame terraces					
16237	68-92	93.0	6.2	0.8	6.0	-	-	-	0.3
16248	38-75	96.7	3.3	T	5.2	-	-	-	-
16359	138-150	93.6	6.4	T	6.5	-	-	-	
				Water sorted upland slopes					
16224	16-32	69.6	28.8	1.6	-	-	-	-	-
16364	25-55	61.4	37.4	1.2	-	-	-	-	-
16367	20-55	63.4	35.7	0.9	-	-	-	-	-

* Fines include mineral material in which the individual particles have a diameter of 2 mm or less.

** Sand - Mineral particles having diameters between 2 and .05 mm.

*** Silt - Mineral particles having diameters between .05 and .002 mm.

****Clay - Mineral particles having diameters of less than .002 mm.

Category I: Wet

This soil drainage class includes a soil moisture environment that is characterized by continuous water logged or submerged conditions throughout the soil. The soil is largely organic and if some mineral material is found in the subsoil it has a predominantly gray or dark gray color.

Category II: Very poorly drained

Soil moisture environment of this category is characterized by practically continuous excess of water throughout the solum. Such conditions are conducive to strong gleying which is reflected in the predominantly gray or dark gray colors of the subsoil.

Category III: Poorly drained

This class of drainage refers to conditions where the lower part of the solum is wet for prolonged periods and only the upper part of the soil is free from excessive moisture periodically. The subsoil has mottled colors in which gray or dark gray is a common component.

Category IV: Somewhat poorly drained

Soils of this class are subject to conditions of excessive water during the first part of the summer but during the later part, these conditions are less prevalent. Mottled colors in which dark grayish brown, instead of gray or dark gray is intermingled with dark brown or dark reddish brown, are common to these soils.

Category V: Moderately well drained

This drainage class refers to conditions where the solum is subject to short intermittent periods of excessive moisture. There are localized areas of mottled colors in such soils in which grayish brown, gray, yellowish brown, and/or dark brown components are present.

Category VI: Well drained

Conditions of excessive moisture are absent or if they do occur, they are infrequent and of short duration in these soils. Mottled colors due to gleying are not present.

Category VII: Excessively drained or dry

Deficiency or scarcity of moisture are characteristic of this drainage class. Rapid runoff, highly porous materials or excessive dessication are the factors that contribute to such conditions.

Ten kinds of soil were identified in the area. A description, together with some laboratory data, are given for each. The Soil Survey Manual (Soil Survey Staff 1951, 1962) is used as the basis for the terminology in the descriptions. A tentative series name has been assigned to each of these soils as shown.

Kangingussa series: This wet soil is characterized by a histic surface horizon having a thickness of over 30 cm. The brown, fibrous, acid organic matter, derived from sedges and mosses, appears to have undergone some physical disintegration and limited humification. Considerable inwashed sandy material is admixed in this soil as a rule. This soil occurs in nearly level, or slightly depressed areas subject to continuous wet conditions.

Profile TAQ129 described and samples about 0.8 km south-southeast of Base Camp in an example of this soil. The area adjoins a shallow pond and free water was present at the soil durface. Carex aquatilis, Eriophorum angustifolium, and moss constitute the vegetative cover. Only occasional small hummocks interrupted the otherwise smooth microrelief. Data for this profile are presented in Table 4.

O11 37 to 33 cm; mixed living and dead remains of roots and stems.

O12 33 to 27 cm; dark brown (7.5 YR 3/2 wet), brown (7.5 YR 5/4 squeezed) partially disintegrated fibrous organic material derived from sedges and moss; numerous roots and stems; lower boundary clear; continuous.

O13 27 to 3 cm; dark brown (10 YR 3/3 wet), yellowish brown (10 YR 5/6 squeezed) partially disintegrated, finely fibrous organic material derived from moss and sedges; strongly resistant to disintegration by rubbing; lower boundary clear wavy; continuous.

O2 3 to 0 cm; very dark brown (10 YR 2/2-3/2 wet), dark brown (10 YR 3/3 squeezed) disintegrated finely fibrous organic material; rubs apart easily; lower clear to abrupt; continuous.

Bg 0 to 3 cm; greenish gray (5 GY 5/1) loamy very fine sand with inclusions and stringers of organic material; frozen below; continuous.

Taserssuak series: Soil of the Taserssuak series is characterized by a moderately thick (10 to 30 cm) histic surface horizon which is underlain by a gray or dark gray strongly gleyed subsoil. It is associated with the very poorly drained soil moisture environments of the areas often bordering Kangingussa soil, or on gentle slopes having a gradient of about 6 per cent or less. Some small hummocks and stones or boulders are often present. A generalized profile description of this soil follows.

O Dark brown or very dark brown when wet and yellowish brown when squeezed partially disintegrated fibrous organic matter, commonly with an intermingling of some dark reddish brown iron oxide rich material near the surface; lower boundary clear or abrupt; acid; continuous; 10 to 30 cm thick.

Bg Gray or dark gray sand, loamy sand, or sandy loam occasionally with some olive brown, yellowish brown, or reddish brown mottling; massive; may have some inclusions and thin streaks of partially altered organic material; acid; frozen below.

An example of Taserssuak series is profile TAQ 130 located in an extensive gently sloping area about 0.7 km south-southeast of Base Camp. The site is on a long (about 300 M) gentle slope having a gradient of 4 to 5

TABLE 4. Organic carbon content, ignition loss, chemical properties, and mechanical composition of Kangingussa soil profile TAQ 129

Ignition	Depth cm.	Ignition wt. loss %	Organic C %	pH	Exch. bases meq./100g Ca	Mg	K	Sum. Exch cations meq./100g	Base sat. %	Free Fe_2O_3 %
O12	33-27	57.9	24.7	4.6	11.7	4.4	0.82	106.0	16	2.0
O13	27-3	60.2	23.3	4.9	9.8	4.2	0.86	87.4	17	0.9
O2	3-0	71.9	31.8	5.5	16.2	9.0	1.32	103.6	26	3.6
Bg	0-3	1.2	0.7	4.5	0.6	0.5	0.05	4.5	27	0.3

Particle Size Distribution (in mm) (per cent)

Ignition	Depth cm.	Very coarse sand 2-1	Coarse sand 1-5	Medium sand .5-.25	Fine sand .25-.1	Very fine sand .1-.05	Total sands	Silt .05-.002	Clay <.002	Tex-tural class
Bg	0-3	0.7	1.0	1.5	15.1	23.6	41.9	57.5	0.6	sil.

per cent. Some hummocks 10 to 20 cm high are present. Free water was present at or within 10 cm of the surface. Carex aquatilis, moss and some Salix sp. constitute the vegetative cover. Table 5 includes some data on this profile.

O11 10 to 17 cm; mat of living and dead stems, roots and leaves.

O12ir 17 to 13 cm; dark reddish brown (2.5 YR 2/4 wet), dark red (2.5 YR 3/6 squeezed) fibrous organic matter with some soft amorphous material; lower boundary clear wavy; acid; horizon is erratic in occurrence and may often be discontinuous.

O13 13 to 14 cm; dark brown (10 YR 3/3 wet), yellowish brown (10 YR 5/4 squeezed), fibrous organic matter; strongly resistent to disintegration by rubbing; considerable admixture or sandy mineral material; lower boundary clear; acid; continuous; organic matter appears to have been derived largely from sedges.

O14 4 to 0 cm; very dark grayish brown (10 YR 3/2 2/2 wet), yellowish brown (10 YR 5/6 squeezed) appreciably disintegrated fibrous organic matter; moderately resistent to disintegration by rubbing; lower boundary abrupt somewhat wavy; acid; continuous.

Bg 0 to 16 cm; gray (5 Y 5/1 moist, 10 YR 6/1 6/2 dry) fine sandy loam with lenses of grit and coarse sand; massive; few roots; acid; frozen below.

Cf 16 to 54 cm; frozen; gray loamy fine sand with some thin lenses of very coarse sand and grit and occasional layers of very dark brown disintegrated fibrous organic material.

Kujatalek series: This very poorly drained soil occurs on somewhat steeper slopes than does the soil of the Taserssuak series. The surface organic horizon is thinner being less than 10 cm, and more frequently it is about 4 to 6 cm thick. Microrelief is usually hummocky (up to 40 cm high), and stones and boulders on the surface are common. In general the morphology of this soil is as follows:

O Dark brown, very dark brown or very dark gray, partially altered, fibrous organic matter occasionally intermingled with some dark reddish brown, especially in the hummocks; lower boundary clear to abrupt; acid; continuous.

Bg Gray or dark gray loamy fine sand or sandy loam often with some yellowish brown, dark brown, or olive brown mottling; massive or weakly subangular structure; streaks of organic matter may be present; acid; continuous.

Profile TAQ 113 described and sampled about 1.5 Km south of Base Camp is an example of the Kujatalek series. It is situated on a long (about 150 m) moderate slope having a gradient of 8 per cent, with a hummocky microrelief of up to 40 cm. Stones and boulders are numerous and in many cases form the cores of the hummocks. Carex sp. and moss make up the vegetation. Free water was encountered at 22 cm depth. Laboratory data for this profile are given in Table 6.

TABLE 5. Organic carbon content, ignition loss, chemical properties, and mechanical composition of Taserssuak soil profile TAQ 130

Horizon	Depth cm.	Ignition wt. loss %	Organic C %	pH	Exch. bases meq./100g Ca	Mg	K	Sum. Exch cations meq./100g	Base sat. %	Free Fe_2O_3 %
O11	19-17	71.4	33.9	5.7	ND	ND	ND	ND	ND	ND
O12ir	17-13	57.5	23.1	5.3	15.2	6.7	2.40	100.9	24	24.9
O13	13-4	30.0	11.5	4.6	3.8	1.2	0.61	42.9	13	2.2
O14	4-0	57.4	21.6	4.5	3.0	1.4	0.70	80.2	6	2.1
Bg	0-16	0.8	0.4	4.7	T	0.2	0.03	1.6	14	0.2

Horizon	Depth cm.	Particle Size Distribution (in mm) (per cent) Very Coarse Sand 2-1	Coarse Sand 1-.5	Medium Sand .5-.25	Fine Sand .25-.1	Very Fine Sand .1-.05	Total Sands	Silt .05-.002	Clay <.002	Tex-tural Class
Bg	0-16	4.3	11.6	14.0	48.9	13.6	92.4	7.1	0.5	s

TABLE 6. Organic carbon content, ignition loss, chemical properties, and mechanical compositions of Kujatalek soil profile TAQ 113

Horizon	Depth cm.	Ignition wt. loss %	Organic C %	pH	Exch. bases meq./100g Ca	Mg	K	Sum. Exch cations meq./100g	Base sat. %	Free Fe_2O_3 %
O12	4-0	47.4	21.1	5.1	6.9	6.4	1.00	69.7	21	3.1
B21g	0-16	1.9	1.0	4.9	1.2	0.7	0.05	5.3	38	0.2
B22g	16-32	4.4	2.2	4.8	0.8	0.6	0.05	9.4	19	0.7

		Particle Size Distribution (in mm)(per cent)								
Horizon	Depth cm.	Very Coarse Sand 2-1	Coarse Sand 1-.5	Medium Sand .5-.25	Fine Sand .25-.1	Very Fine Sand .1-.05	Total Sands	Silt .05-.002	Clay <.002	Tex-tural Class
B21g	0-16	2.3	5.8	8.7	28.4	22.7	67.9	30.9	1.2	fsl
B22g	16-32	2.7	10.0	11.2	28.0	17.7	69.6	28.8	1.6	fsl

O11 5 to 4 cm; mat of roots and stems, living and dead.

O12 4 to 0 cm; very dark brown (10 YR 2/2 wet), dark brown (10 YR 3/3 squeezed), finely fibrous organic material; strongly resistant to disintegration by rubbing; lower boundary abrupt, wavy; acid; continuous.

B21g 0 to 16 cm; gray to dark gray (5 Y 5/1 - 4/1 moist, 10 YR 6/1 dry) fine sandy loam with few, fine, dark yellowish brown (10 YR 4/4) mottles along some roots; massive with tendency to break up into weak fine subangular units; roots plentiful; acid; lower boundary gradual; continuous.

B22g 16 to 32 cm; gray (5 Y 5/1 4/1 moist, 10 YR 6/1 dry) fine sandy loam with inclusions of thin streaks of dark brown (7.5 YR 3/2) organic material; massive; acid; continuous; frozen below.

Tartrat series: This poorly drained soil frequently occupies moderately to strongly sloping benched tracts of the long valley slopes. There is considerable skeletal material in this soil as a rule and frequently numerous stones and boulders appear at the surface. Hummocks of low relief are common in areas where this soil occurs. The following is a generalized description.

O Dark brown, very dark brown, or black, fibrous organic matter which may be intermingled with some dark reddish brown; lower boundary clear or abrupt, wavy; acid; continuous; thickness is less than 10 cm and most commonly is about 5 cm.

Bg Grayish brown, light olive brown or dark grayish brown fine sandy loam or loamy fine or very fine sand; distinctly mottled in which gray, dark brown, or reddish brown are common component colors; massive with some indication or weak platiness; contorted streaks of organic matter indicate appreciable disturbance; acid; continuous.

An example of the Tartrat series is profile TAQ 161 described and sampled about 4 Km south of Base Camp. The site examined is on a moderately sloping (10% gradient) tract about 75 m long. The general gradient of the valley slope in the area is about 15 per cent. Hummocky microrelief of about 20 cm is prevalent in the vicinity of the site and there are numerous stones and boulders. Carex sp and moss dominate the vegetation. Free water was encountered at a depth of 15 cm. Pertinent data for this profile are given in Table 7.

O1 7 to 4 cm; mat of roots and stems.

O2 4 to 0 cm; black (5 YR 2/1 wet), dark brown (7.5 YR 3/2 squeezed), moderately fibrous organic matter; moderately resistent to disintegration by rubbing; lower boundary clear or abrupt, very wavy; acid; continuous; thickness ranges from 2 to 7 cm at the site.

B2g 0 to 20 cm; light olive brown (2.5 Y 5/4) fine sandy loam with coarse, common, olive brown (2.5 Y 4/4), olive gray (5 Y 5/2) and dark brown (7.5 YR 4/4) mottling; massive with some indication of very weak, thick platiness; roots plentiful in upper part and few in lower; lower boundary gradual; acid; continuous.

TABLE 7. Organic carbon content, ignition loss, chemical properties and mechanical composition of Tartrat soil profile TAQ 161

Horizon	Depth cm.	Ignition wt. loss %	Organic C %	pH	Exch. bases meq./100g Ca	Mg	K	Sum. Exch cations meq./100g	Base sat. %	Free Fe_2O_3 %
02	4-0	27.6	15.0	5.4	17.7	4.8	0.56	50.8	45	0.8
B2g	0-20	1.0	0.6	5.4	0.8	0.5	0.05	4.5	31	0.2
B3	20-55	0.8	0.4	5.4	0.4	0.4	0.05	3.2	28	0.5

Horizon	Depth cm.	Particle Size Distribution (in mm)(per cent) Very Coarse Sand 2-1	Coarse Sand 1-.5	Medium Sand .5-.25	Fine Sand .25-.1	Very Fine Sand .1-.05	Total Sands	Silt .05-.002	Clay <.002	Tex-tural Class
B2g	0-20	4.3	10.2	9.2	22.0	19.4	65.1	33.6	1.3	fsl
B3	20-55	2.8	10.3	9.1	22.0	19.2	63.4	35.7	0.9	fsl

B3 20 to 55 cm; light olive brown (2.5 Y 5/4) fine sandy loam with coarse, common, olive brown mottling; massive; frozen below.

Oxford Creek series: Commonly occupying the benched tracts of the middle and upper portions of the valley slope, this somewhat poorly drained soil occurs on surfaces that may range from moderately sloping to very steep, gradients 12 to 40 per cent. It has been derived from materials resulting from partial alteration or reworking of till by surface and subsurface flow of water originating as precipitation runoff or from the melting of the snowbanks. These materials generally have a higher content of silt, and fine and very fine sand than do the other surficial materials of the area. Hummocks of low relief and numerous stones and boulders are common to the areas occupied by this soil. In general, the morphology of the soil is as follows:

O Dark brown, very dark brown, or dark reddish brown fibrous organic matter; clear to abrupt wavy boundary; acid; continuous; thickness is less than 10 cm and most commonly is in the 2 to 5 cm range.

C1 Dark grayish brown fine or very fine sandy loam, loamy very fine sand or loamy fine sand with faint to distinct dark brown, dark reddish brown, olive brown or dark yellowish brown mottling; massive with some indications of weak platiness; contorted zones of colors and streaks of organic matter inclusions are indicative of considerable mixing and disturbance that apparently occur in such materials.

The profile of this soil described below was examined about 4 km south-southeast of Base Camp. The benched tract on which the site occurs had a gradient of 14 per cent while the general slope was about 18 per cent. Hummocky microrelief of about 20 cm and stones and boulders are common to the area. The vegetation consisted of Carex and Vaccinium sp., moss and lichens. Laboratory data for this profile are given in Table 8.

O1 7 to 5 cm; mat of living and dead roots, stems, and leaves.

O2 5 to 0 cm; dark brown (10 YR 3/3) finely disintegrated somewhat fibrous organic material; soft, rubs down easily; lower boundary clear wavy; acid; continuous; thickness at site ranges 2 to 5 cm.

C1 0 to 25 cm; dark grayish brown (2.5 Y 4/2) very fine sandy loam with coarse diffuse dark reddish brown (5 YR 3/3), olive brown (2.5 Y 4/4), and dark yellowish brown mottling; massive or somewhat weak, thick platy structure; roots plentiful; pebbles and stones make up about a third of the volume; acid; lower boundary gradual.

C2 25 to 55 cm; dark grayish brown (2.5 Y 4/2) very fine sandy loam with few, large olive brown (2.5 Y 4/4) mottles; massive or somewhat weak platy structure; roots very few; frozen below; some free water above the frozen zone.

Base series: This moderately well drained soil has been derived from sandy materials of the outwash and/or kame terraces and hence is coarse textured throughout. An example of this soil is profile TAQ 139 examined about

TABLE 8. Organic matter content, ignition loss, chemical properties, and mechanical composition of Oxford Creek soil profile TAQ 160

Horizon	Depth cm.	Ignition wt. loss %	Organic C %	pH	Exch. bases meq./100g Ca	Exch. bases meq./100g Mg	Exch. bases meq./100g K	Sum. Exch cations meq./100g	Base sat. %	Free Fe_2O_3 %
C1	0-25	3.3	1.7	5.1	0.8	0.4	0.08	9.2	14	0.6
C2	25-55	1.8	.9	5.1	0.4	0.6	0.05	5.5	20	0.3

Particle Size Distribution (in mm)(per cent)

Horizon	Depth cm.	Very Coarse Sand 2-1	Coarse Sand 1-.5	Medium Sand .5-.25	Fine Sand .25-1	Very Fine Sand .1-.05	Total Sands	Silt .05-.002	Clay <.002	Tex-tural Class
C1	0-25	1.1	4.1	7.1	29.3	25.5	67.1	31.6	1.3	fsl
C2	25-55	0.8	3.8	5.9	23.1	27.8	61.4	37.4	1.2	vfsl

150 m north of Base Camp. It occurs in a slightly depressed area on the extensive terrace. Vaccinium and some Carex spp. are the predominant constituents of the vegetation. Weakly expressed nonsorted net about 2 m across form the ground pattern and a low microrelief of about 10 cm is present at the site. Some data for this profile are given in Table 9.

O1	2 to 0 cm; mat of stems, roots and leaves.
A1	0 to 6 cm; black (10 YR 2/1) sand with a high content of organic matter; weak coarse crumb structure; friable; roots plentiful; acid; lower boundary clear but irregular due to contortions; thickness at site ranged from 2 to 15 cm; continuous.
B & A2	6 to 17 cm; intermingled light yellowish brown (10 YR 6/4) and gray (10 YR 6/1) sand with some grayish brown (2.5 Y 5/2) and some very dark grayish brown (10 YR 3/2) inclusions of A1 horizon material; considerably contorted; massive; friable; roots plentiful; acid; lower boundary clear to gradual.
B	17 to 41 cm; dark grayish brown (2.5 Y-10 YR 4/2) sand with many fine, faint yellowish brown (10 YR 5/6) mottles; massive; soft; roots very few; acid; lower boundary clear, slightly wavy.
C	41 to 67 cm; dark grayish brown (10 YR 4/2) coarse sand with occasional pebbles; loose; wet; acid; frozen below.

Quantum series: Soil of the Quantum series occurs on nearly level or gentle sloping areas in the vicinity of Lake Quantum (Fig. 1 in Part I). Although it shows but weak profile development, it is considered to be moderately well drained because of interming of grayish brown and yellowish brown colors near the surface.

Profile TAQ 150 examined about 100 m north of Lake Quantum is located on a long (about 300 m) gentle slope having a gradient that ranges from 2 to 5 percent. A stabilized net ground pattern 1 to 2 m across with depressed borders about 15 cm deep imparts a slight microrelief to area. About 10 per cent of the surface is occupied by boulders. Carex and Draba sp. and moss form the vegetative cover. The soil was described and sampled near the center of one of the nets. Data available for this soil are reported in Table 10.

O1	3 to 0 cm; mat of roots and stems, some of which have been partially humified.
A1	0 to 5 cm; dark grayish brown (2.5 Y 4/2) loamy fine sand intermingled or mottled with yellowish brown (10 YR 5/6); slightly acid; lower boundary clear wavy; thickness ranges from 2 to 10 cm.
C	5 to 40+ cm; olive gray (5 Y 5/2) loamy fine sand with considerable grit; massive, vesicular; firm; some inclusions of streaks of organic matter; slightly acid.

TABLE 9. Organic carbon content, ignition loss, chemical properties, and mechanical composition of Base soil profile TAQ 139

Horizon	Depth cm.	Ignition wt. loss %	Organic C %	pH	Exch. bases meq./100g Ca	Mg	K	Sum. Exch cations meq./100g	Base sat. %	Free Fe_2O_3 %
O1	2-0	70.4	30.4	4.7	11.4	9.5	2.71	65.3	36	ND
A1	0-6	8.8	4.2	5.0	1.8	2.3	0.13	17.0	26	0.4
B & A2	6-17	1.3	0.7	5.5	0.5	0.6	0.05	3.8	32	0.4
B	17-41	0.9	0.4	5.8	0.4	0.6	0.04	2.6	38	0.4
C	41-67	0.4	ND	5.9	0.6	0.5	0.05	2.6	46	0.2

Particle Size Distribution (in mm)(per cent)

Horizon	Depth cm.	Very Coarse Sand 2-1	Coarse Sand 1-.5	Medium Sand .5-.25	Fine Sand .25-1	Very Fine Sand .1-.05	Total Sands	Silt .05-.002	Clay <.002	Textural Class
A1	0-6	4.1	22.7	21.8	33.0	6.1	87.7	11.8	0.5	cs
B & A2	6-17	2.2	15.7	20.9	41.1	12.6	92.5	7.1	0.4	s
B	17-41	3.1	19.3	19.7	38.6	11.9	92.6	7.1	0.3	s
C	41-67	8.5	54.8	20.1	11.5	3.2	98.1	1.8	0.1	cs

TABLE 10. Organic carbon content and pH of Quantum soil profile TAQ 150

Horizon	Depth cm.	Organic C %	pH
A1	0-5	0.6	5.2
C	5-25	ND	6.2
C	25-40	ND	6.5

Tasersiaq series: This well drained soil is one of the more extensive ones in the area, occupying most of the nearly level to moderately sloping portions of the outwash or kame terraces. Having been derived from glaciofluvial deposits, it is coarse textured and readily permeable and shows a rather distinct morphology to a greater depth than do the other soils. Because of its coarse texture and the topographic positions it occupies, it is susceptible to serious wind erosion.

The following is a generalized description of this soil:

A1 Dark grayish brown to black loamy sand; weak crumb structure; friable; roots abundant; acid; lower boundary clear, wavy to irregular, apparently due to contortions; continuous; thickness ranges 4 to 15 cm.

A2 & B Intermingled gray, grayish brown or pale brown and yellowish brown, dark yellowish brown or very dark grayish brown sand or loamy sand; acid; considerable contorting evident; thickness ranges from 0 to about 20 cm.

B2 Yellowish brown or dark yellowish brown loamy sand or sand with some patches of strong brown color; weak crumb structure; some gravel may be present; acid; thickness ranges 12 5o 20 cm.

B3 Pale brown or light yellowish brown, loamy sand or sand with or without gravel; medium or slightly acid; lower boundary gradual.

C Sand or sand and gravel; frozen zone in late summer at a depth of about 1.5 to 2 m.

Profile TAQ 158 described and sampled about 500 m northeast of Base Camp is representative of this soil. The site is a nearly level area supporting a stand of vegetation consisting of Carex, Agropyron, Silene and Rychomytrium spp. Data for this profile are given in Table 11.

A1 0 to 9 cm; dark grayish brown (10 YR 4/2) loamy sand; weak fine granular structure; friable; roots abundant; lower boundary clear, very wavy due to contorting; continuous; thickness ranges from 9 to 15 cm.

A2 Erratic and patchy in distribution. Where present it occurs as a thin streak (about 1 cm thick) having a pale brown (10 YR 6/3) color.

TABLE 11. Organic carbon content, ignition loss, chemical properties and mechanical composition of Tasersiaq soil profile TAQ 158

Horizon	Depth cm.	Ignition wt. loss %	Organic C %	pH	Exch. bases meq./100g Ca	Mg	K	Sum. Exch cations meq./100g	Base sat. %	Free Fe_2O_3 %
A1	0-9	2.6	1.2	5.8	2.2	1.2	0.13	7.0	50	0.4
A2	Patchy	2.0	0.7	5.8	1.7	1.0	0.05	5.5	51	0.3
B2	9-26	1.0	0.4	5.7	0.7	0.7	0.08	4.1	37	0.3
B31	26-38	0.7	0.2	6.0	0.7	0.8	0.08	2.6	46	0.4
B32	38-58	0.4	0.1	6.5	1.1	0.6	0.05	2.6	69	0.3
C	58-138	0.2	ND	7.0	0.3	0.3	0.05	0.8	88	0.2
Cf	138-150	0.1	ND	6.7	0.6	0.2	0.05	1.2	76	ND

Horizon	Depth cm.	Particle Size Distribution (in mm)(per cent) Very Coarse Sand 2-1	Coarse Sand 1-.5	Medium Sand .5-.25	Fine Sand .25-1	Very Fine Sand .1-.05	Total Sands	Silt .05-.002	Clay <.002	Textural Class
A1	0-9	3.4	19.2	18.3	30.3	13.4	84.6	15.1	0.3	ls
A2	Patchy	3.2	16.3	20.5	34.0	12.6	86.6	12.9	0.5	s
B2	9-26	1.1	9.0	15.2	37.7	17.0	80.0	19.6	0.4	ls
B31	26-38	9.7	27.2	14.5	22.9	12.0	86.3	13.3	0.4	lcs
B32	38-58	17.2	41.0	13.8	14.8	4.3	91.1	8.8	0.1	cs
C	58-138	5.7	31.8	31.0	26.8	3.1	98.6	1.4	0.1	cs
Cf	138-150	4.1	31.8	26.6	24.7	6.4	93.6	6.4	T	cs

B2 9 to 26 cm; yellowish brown (10 YR 5/4) loamy sand with thin patches of dark yellowish brown (10 YR 4/4) along upper boundary; massive in place breaking into very weak very fine subangular or crumb structure; roots plentiful; few pebbles present with dark reddish brown staining on lower surfaces; lower boundary gradual.

B31 26 to 38 cm; light yellowish brown (10 YR 6/4 5/4) loamy coarse sand; about 50 per cent of volume is made up of rounded pebbles and small cobbles with dark reddish brown (5 YR 3/3) staining on lower surfaces; roots plentiful.

B32 38 to 58 cm; pale brown (10 YR 6/3) to light yellowish brown (10 YR 6/4) coarse sand; rounded pebbles and small cobbles make up about 60 to 70 percent of volume; roots plentiful; olive (5 Y 3/3) to light olive brown (2.5 Y 5/4) coatings of silty vesicular material on upper surfaces of pebbles, dark reddish brown (5 YR 4/4 3/3) staining and white calcareous coatings on lower surfaces.

C 58 to 138 cm; sand and gravel of mixed colors and lithology; bedded.

Cf 138 to 150 cm; frozen; grayish brown (2.5 Y 5/2) coarse sand.

Safartoq series: The well drained safartoq soil is similar to that of the Tasersiaq series in the sequence of horizons but is somewhat less coarse textured since it is derived from till. It occurs most commonly on the moderately to very steeply sloping terrain. As such, the materials are subject to appreciable mass movement down slope which is reflected in some disturbance of the soil profile. This in general has contributed to a weaker expression of the A2 and B horizons. A high content of skeletal material in the solum and stone or boulder littered surfaces are common to the areas occupied by this soil. Fine sandy loam and loamy fine sand are the textures most common to this soil.

A soil profile, TAQ 124, examined about 0.6 Km south-southwest of the Base Camp is an example of this soil. The profile, however, does exhibit a somewhat stronger development of the B horizon than usually found in the soil of this series. This site is on a 25 per cent slope of which about 25 per cent of the surface is occupied by lichen covered stones and boulders and about 15 per cent is free of vegetation. The vegetative cover consists of Dryas and Carex sp and some grasses and lichens. Data for some chemical properties of this soil are shown in Table 12.

O1 2 to 0 cm; mat of roots, stems, and lichens.

A1 0 to 4 cm; very dark grayish brown (10 YR 3/2) fine sandy loam; weak fine crumb structure; friable; discontinuous; thickness ranges from 0 to 4 cm. Thin patches of gray fine sandy loam adjoin pebbles and stones indicating an incipient development of A2 horizon.

B 4 to 10 cm; yellowish brown (10 YR 5/4) fine sandy loam; weak fine granular structure; friable; lower boundary clear to abrupt, wavy; continuous; thickness ranges from 2 to 10 cm.

TABLE 12. Organic carbon content, ignition loss, chemical properties and mechanical composition of Safartoq soil profile TAQ 124

Horizon	Depth cm.	Ignition wt. loss %	Organic C %	pH	Exch. bases meq./100g Ca	Mg	K	Sum. Exch cations meq./100g	Base sat. %	Free Fe_2O_3 %
A1	0-4	5.1	2.3	5.8	3.9	2.4	0.20	13.7	47	0.7
B	4-10	2.6	1.0	5.8	1.2	1.1	0.08	9.8	24	1.0
C1	10-36	0.8	0.3	5.7	0.3	0.4	0.05	3.1	26	0.4
B	10-36	2.7	ND	5.6	1.0	0.7	0.05	10.4	17	1.0
C2	36-80	0.6	0.18	5.8	0.4	0.4	0.05	3.7	24	0.6

Particle Size Distribution (in mm)(per cent)

Horizon	Depth cm.	Very Coarse Sand 2-1	Coarse Sand 1-.5	Medium Sand .5-.25	Fine Sand .25-1	Very Fine Sand .1-.05	Total Sands	Sile .05-.002	Clay <.002	Tex-tural Class
A1	0-4	5.2	10.8	8.8	19.8	17.4	62.0	32.6	5.4	fsl
B	4-10	4.4	8.9	8.4	19.2	15.7	56.6	35.8	7.6	fsl
C1	10-36	5.4	12.6	9.0	22.6	18.1	67.7	30.6	1.7	fsl
B	10-36	9.4	8.2	7.1	16.9	14.2	50.8	41.3	7.9	fsl
C	C2	4.2	10.7	8.4	22.1	19.6	65.0	34.2	0.8	fsl

C1 & B 10 to 36 cm; gray (5 Y 5/1) fine sandy loam intermingled with masses of dark yellowish brown (10 YR 4/4) and light yellowish brown (10 YR 6/4) soil similar to that of the B horizon; gray soil is massive and vesicular while the B horizon inclusions are weak fine granular; roots plentiful; lower boundary abrupt and irregular.

C2 36 to 80 cm; olive gray (5 Y 5/2) fine sandy loam with occasional thin horizontal streaks of dark yellowish brown; massive, vesicular.

The intermingling of the gray and dark yellowish brown material in C1 horizon is indicative of appreciable mixing by downslope mass movement. These two kinds of material in the C1 & B horizon were sampled separately for analysis. About 30 per cent of the soil volume is made up of rock fragments of various sizes.

Avongnatdleq series: This well to somewhat excessively drained soil has been derived from till and usually occurs on the upper slopes as well as on the crests and shoulders of the upland terrain. Morphologically it exhibits but little development in color - usually the upper part of the profile is only slightly darker than the subsoil or parent material. Lower pH values and the absence of the calcareous fraction in the upper part of the solum, however, are indicative of some leaching.

Derived from till, this soil is coarse textured. Sandy loams and loamy fine sand are the common texture classes. A large proportion of the soil volume, estimated 30 to 60 per cent, is made up of skeletal material. Stones and boulders litter the surface and occupy a considerable portion of the surface.

Vegetation consisting of isolated mats of Dryas sp. and some Carex sp. and lichens is sparse, generally covering only a minor portion of the soil surface.

An example of the Avanguatdleq soil is profile TAQ 157 examined about 1 km south-southwest of Base Camp. It is located on the crest of Camp Creek Moraine.

A description of this profile follows while some data regarding chemical properties are shown in Table 13.

A1 0 to 2 cm; pale brown (10 YR 6/3) loamy sand; loose; roots few; lower boundary clear; discontinuous.

B 2 to 15 cm; grayish brown (2.5 Y 5/2) loamy sand with some patches of yellowish brown (10 YR 5/4) adjacent to rock fragments; somewhat massive in place; friable; roots plentiful; lower boundary wavy or irregular; discontinuous.

C1 15 to 33 cm; olive gray (5 Y 5/2) fine sandy loam; massive in place; very few roots; lower boundary gradual.

C2 33 to 117 cm; olive gray (5 Y 5/2) fine sandy loam with light brownigh gray (5 Y 6/2) around rock fragments; somewhat massive in place; losse when removed.

TABLE 13. Organic carbon content, chemical properties and mechanical composition of Avongnatdleq soil profile TAQ 157

Horizon	Depth cm.	Organic C %	pH	$CaCO_3$ Equiv. %	Exch. bases meq./100g			Sum. Exch cations meq./100g	Base sat. %	Free Fe_2O_3 %
A1	0-2	0.7	6.6	-	1.3	1.4	0.28	3.9	77	0.4
B	2-5	0.2	7.2	-	0.7	0.8	0.08	2.5	64	0.3
C1	15-33	ND	7.4	T	-	-	-	-	-	0.3
C2	33-66	ND	7.4	T	-	-	-	-	-	0.4
C2	66-100	ND	7.5	T	-	-	-	-	-	0.4
C2	100-117	ND	7.8	0.05	-	-	-	-	-	0.4
C3	117-126	ND	8.3	1.10	-	-	-	-	-	0.4

Horizon	Depth cm.	Particle Size Distribution (in mm)(per cent) Very Coarse Sand 2-1	Coarse Sand 1-.5	Medium Sand .5-.25	Fine Sand .25-.1	Very Fine Sand .1-.05	Total Sands	Silt .05-.002	Clay <.002	Textural Class
A1	0-2	7.3	16.0	11.9	24.0	18.4	77.6	22.1	0.3	ls
B	2-15	7.2	12.2	10.3	24.2	19.3	73.2	26.6	0.2	ls
C1	15-33	4.0	10.7	10.4	24.7	18.2	68.0	30.8	1.2	fsl
C2	33-66	4.7	10.6	9.3	20.2	16.9	61.7	35.8	2.5	fsl
C2	66-100	3.9	10.0	9.1	21.5	18.0	62.5	34.5	3.0	fsl
C2	100-117	4.8	14.1	11.9	25.2	15.9	71.9	25.3	2.8	sl
C3	117-125	6.9	16.0	11.0	22.2	14.4	70.5	24.8	4.7	fsl

C3 117 to 125+ cm; olive gray (5 Y 4/2) sandy loam with considerable grit; slightly calcareous.

Classification of Soils

A classification of the ten soil series occurring in the Tasersiaq area has been made according to Tedrow et al (1958), Tedrow and Cantlon (1958), and Soil Survey Staff (1960). The classification shown in Table 14 is into Great Soil Groups and Great Group classes. Classification into subgroups according to Soil Survey Staff (1960) will be made in a supplement to the current report.

TABLE 14. Classification of soils of Tasersiaq area into Great Soil Groups according to Tedrow and Cantlon (1958) and Tedrow et al (1958) and into Great Groups according to Soil Survey Staff (1960).

Soil Series	Great Soil Group	Great Group
Kangingussa	Half-bog	Histosols (order category)
Tasserssuak	Half-bog	Cryaquepts
Kujatalek	Wet Meadow	Cryaquepts
Tartrat	Wet Meadow	Cryaquepts
Oxford Creek	Upland Tundra	Cryorthents
Base	Arctic Brown	Cryopsamments
Quantum	Upland Tundra	Cryopsamments
Tassersiaq	Arctic Brown	Cryopsamments
Safartoq	Arctic Brown, Minimal	Cryochrepts
Avangnatdleq	Polar Desert	Cryochrepts

SUMMARY

1. Climate, topography, parent materials and soil moisture environments of the area are discussed as factors influencing soil formation.

2. Ten kinds of soils, each soil having a distinctive morphology have been recognized in the area. Each of these soils is described and data pertaining to their chemical properties are presented. A tentative soil series name has been assigned to each of the soils.

3. A classification of the soils into Great Soil Groups and into Great Groups has been made.

4. A supplement to this report will be submitted later. This latter report will contain additional information on the physical and chemical properties of the soils and also will include a soils map of the area. Data pertaining to retention and release by selected soils of radioactive isotopes will also be presented.

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See composite list at end of report.

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13. ABSTRACT During the summer 1964, personnel of The Ohio State University Institute of Polar Studies conducted a field program in the Sukkertoppen Ice Cap area of southwest Greenland. The program included studies of soil and mass wasting in the Tasersiaq area immediately east of the ice cap, and studies of the microclimatology across the eastern edge of the ice cap.

The results of this research program are contained in four parts. Part I, by Adolph Kryger, discusses the microclimatological (excluding radiation) results of observations taken at four stations, one at the base of the slope below the eastern edge of the Sukkertoppen Ice Cap, two intermediate ones on the slope, and one at the edge of the glacier. Part II, by Fritz Loewe, discusses the radiation observations. Both have related their observations to those at other permanent stations along the western Greenland coast. Part III, by K. R. Everett, presents the results of studies of mass-wasting and patterned ground phenomena. Part IV, by N. Holowaychuk and K. R. Everett, contains most of the results of the pedological studies. The report herein includes the discussion of soil morphology, chemistry, and classification.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Microclimatology Climatology Pedology Geomorphology Mass wasting Soils Patterned ground Sukkertoppen Ice Cap Tasersiaq Greenland						

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